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THE SEMICENTENNIAL LECTURES

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Foreword

CHARTERED by its founder in 1891 as the William Marsh Rice Institute, the present Rice University began its first session with an entering class of seventy-seven students on September 23, 1912, under the presidency of Edgar Odell Lovett. The opening of the institution was celebrated formally by an Academic Festival held on October 10, 11, and 12, 1912. The first two days were featured by a series of lectures either read by title or delivered by a distinguished group of eleven internationally renowned scholars, and the final day was set aside for the formal dedication of the new university. The lecturers included Rafael Altamira y Crevea, Emile Borel, Benedetto Croce, Hugo de Vries, Sir Henry Jones, Baron Dairoku Kikuchi, John William Mackail, Wilhelm Ostwald, Sir William Ramsay, Frederik Carl Størmer, and Vito Volterra. The last-named also presented a eulogy on Henri Poincaré, whose untimely death prevented his participation in the Academic Festival. These lectures along with other material relating to the opening of the University are printed in the three volumes of *The Book of the Opening of the Rice Institute.*

During the ensuing fifty years, the Rice Institute grew in size and prestige as it followed the course laid out by President Lovett. Dedicating itself to the pursuit of excellence, it limited its undergraduate enrollment to about 450 Freshmen each year. Following the end of World War II, Dr. Lovett retired and was succeeded as President in 1946 by Dr. William V. Houston. Under Dr. Houston there were a renewed period of growth in faculty and physical plant and an increased emphasis upon research and graduate study. President Houston retired in 1960, and Dr. Carey Croneis, the Provost, served as Acting President until July 1, 1961, when the Board of Governors elected Dr. Kenneth Sanborn Pitzer as the third President. The institution had meanwhile assumed the title of William Marsh Rice University on July 1, 1960, to correct the impression held by many that the Rice Institute was a technical school.

The inauguration of President Pitzer opened the program for a three-day observance of the Rice Semicentennial on October 10, 11, and 12, 1962. The inaugural ceremonies, the Semicentennial Convocation, and the dinners held on the evenings of those days are recorded in another volume of the Rice University Semicentennial Publications. In it are to be found addresses by President Pitzer, Dr. T. Keith Glennan, Dr. Harry H. Ransom, Dr. Glenn T. Seaborg, Professor Arnold Toynbee, and Dr. William G. Pollard, along with remarks by Dr. Houston, Dr. Croneis, and a number of others.

The present volume includes the eighteen public lectures delivered on October 11 and 12, 1962, by the distinguished scholars who took part in the Semicentennial Academic Festival. This was opened by the address of Professor Toynbee at the Semicentennial Convocation (also printed in the volume mentioned above), which was followed by seventeen lectures given on the afternoon of October 11 and the morning and afternoon of October 12.

Professor Toynbee considers the great changes which took place in the position of the United States in world affairs during the half-century just past, while Professor Viner analyzes the United States in terms of its economic structure. Professors Blanshard and Peyre survey American university education from the vantage point of the humanist and moralist, while Mr. Reid discusses architecture and education with emphasis on the preservation of the artist as an individual in an increasingly complex and institutionalized environment. Professor Nevins considers the respective roles of public and private universities in present-day America, and Professor Yagi discusses the impact of the war and American occupation on engineering education in Japan. Professor Landré looks forward to a reunited western European culture as one of the most desirable by-products of the growing economic and political unity arising from the European Common Market. Professor Bronson analyzes a folk song and illustrates the uses to which modern technology can be put in research in the humanities.

Most of the remaining lectures consider the recent development and present status of their particular fields of interest. Dr. Ewing presents the exciting possibilities for geology through the new studies of ocean sediments. Sir George Thomson analyzes the changes in physics and emphasizes the great significance of computers. Professor Shannon reviews the development of computers and considers their future uses and applications. Professor Prelog emphasizes the basic significance of the concept of steric strain as a unifying approach in organic chemistry. Dr. Szent-Györgyi surveys the past and looks forward to a fruitful and exciting future of biological research in the world of energy, quanta, electrons, and atomic nuclei. Professor Stüssi

traces the growing use of science and mathematics in structural engineering and stresses the necessity of maintaining a balance between the theoretical and the practical for sound progress. Professor Leray considers Cauchy's problem, which once presented a unifying mathematical concept for physics and which still offers possibilities even for the complexities of present-day physics. Interestingly enough, he deals with a problem discussed in one of the lectures by Professor Borel in 1912.

Diverse as these lectures may seem at first sight, they are for the most part unified in their explicit or implicit concern with the problems arising out of the explosive acceleration of knowledge in science and technology and the changes this has produced and is producing. Something of this feeling is presented by Sir Geoffrey Taylor's rather nostalgic look at a less hurried day when those laymen without formal scientific training might contribute much to knowledge through "scientific diversions." Dr. Mead, viewing matters as an anthropologist, admits the rapid expansion of knowledge but states flatly that man has the capacity to master it all provided he is given time.

Her concern with man's ability to control his environment without suicidal warfare is echoed in other lectures. This uneasiness over man's political deficiencies is paralleled by other questionings. Can man master the flood of new learning without a specialization so rigorous as to destroy intercommunication and a meaningful perspective of life as a whole? What objectives should we seek in our university education? Should we attempt to produce well-rounded individuals or highly specialized research scholars and scientists?

Similar problems were considered by the lecturers of 1912, but theirs was an age of less rapid change, and they were able to reason from what seemed to be completely rational and dependable physical laws. They were certain that they lived in a stable society, and they spoke with a quiet confidence that the problems they faced would be solved through reason and patience. The Semicentennial lecturers exhibit an obvious pride and often an exuberant anticipation as they view the past accomplishments and the future expansion of their special areas of knowledge. They lack, however, the confidence in the stability of their society; they have less assurance of the universal applicability of physical laws. They reflect clearly their own times as they view man, science, learning, and education in the fall of 1962.

One may wonder how these matters will appear to the distinguished lecturers for the Centennial Academic Festival of Rice University in October, 2012.

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ARNOLD JOSEPH TOYNBEE

The Changes in the United States Position and Outlook as a World Power during the Last Half-Century

WE HAVE GATHERED here at Rice University this week to celebrate one of the notable achievements of the last half-century. Within these last fifty years, Rice University has made its passage from birth to maturity. There can be no greater change than that; it is the greatest change conceivable, and it has taken place within a span of time that is short on any standard of measurement. A half-century is shorter even than that proverbial symbol of brevity, the average span of a human lifetime; it is shorter, indeed, than the present average length of a working lifetime between childhood at one end and senility or death at the other. In this room at this moment there must be among us a number of Rice alumni who graduated in the first class. I am sure these have all retained their native Texan vigor, including their full powers of memory. If one is in one's early seventies today, and if one has kept his wits, one has more to remember, I should guess, than any previous generation has ever had. Our lifetime has been crowded with events. The magnitude of the change that has taken place on this campus within this last half-century is matched by the magnitude of the contemporary change in the rest of the United States and in the whole world.

My subject this morning is, as you know, the change in the United States position and outlook during this last half-century. It may seem audacious for a foreigner to offer to talk to an American audience about this. A foreigner's view is inevitably superficial, and he is

ARNOLD JOSEPH TOYNBEE is professor emeritus of international history at the University of London and is widely known for his monumental study of the rise and decline of civilizations. This lecture was presented at the Semicentennial Convocation of Rice University at the Houston Music Hall on the morning of October 11, 1962.

sure to overlook many important points that are obvious to American eyes. I have been emboldened by two things. One of them is that an inside view, such as my audience has, may sometimes miss seeing points that are visible to an outsider, such as I am. An outsider's attention may sometimes be caught by points that are ignored by Americans because these points are so familiar to American minds that they take them for granted. My second reason for choosing this subject is that, within these last fifty years, the United States position and outlook have ceased to be just the private concern of the people of the United States and have become one of the major public concerns of the human race. This has been an awkward change for both the United States and the world. It is unpleasant to lose one's privacy; it is also unpleasant to lose one's independence and to find one's fate hanging on other people's decisions, and no longer just on one's own. These two awkward changes have, between them, revolutionized the relations between the United States and the world in the course of the last half-century, and, in revolutionizing them, have put a considerable strain on them. This particular change is at the very heart of my subject, so I shall be coming back to consider it more than once before I have done.

I have perhaps one slight personal advantage for discussing the change in the United States position since 1912. I have known the United States since that year. It is true that I did not set foot in the United States till 1925, but in 1912 I met the United States in Greece and got my first sight of her, as a foreigner should perhaps get it, through the eyes of immigrants. In 1912 Greek emigration to the United States was at its peak, and every Greek village was full of emigrants who had made enough money on this side of the Atlantic to pay for a visit to their home in Greece. The more remote and the less prosperous the village was, the larger the percentage of its population that had crossed the Atlantic to improve its condition.

By 1912 the flowing tide of Greek migration had just reached the Middle West. As I talked to people in the village store in the evening, Kansas City and Omaha, which had been only names for me before, became vivid and thrilling realities. I could now picture their beautiful asphalt sidewalks, along which one could walk with impunity in glacé-kid shoes. Anyone in this room who has walked over the mountains of Greece will appreciate that a city where one could tread smoothly seemed, to a Greek immigrant, like some incredibly glorious New Jerusalem. This was the first account of the United States that I had had from firsthand witnesses, and their report was enthusiastic. Here was a land of promise; and the best thing about it was that the access was entirely free. You could just take a passage and go there (an

immigrant's fare was cheap even by Greek standards at the time). What a contrast to a benighted country like, say, Turkey, where you were not allowed to land without showing a passport and being examined by the police. I shall come back to this question of immigration, too. One of the major changes in the past half-century is concerned with that.

To appreciate the extent of the change in the United States position during this last half-century, one must find some yardstick for measuring it. There are two obvious yardsticks for the purpose. One can compare this last half-century in the United States with the same half-century in the world as a whole, or one can compare it with the preceding half-century in the United States itself.

The pace of change in the United States since 1912 seems headlong when one measures it by the pace during the fifty years before 1912. That was the half-century between the end of the War between the States and the beginning of the First World War; and that was a relatively stable half-century in the history of the United States. The result of the War between the States (may I call it—as foreigners do call it—the Civil War, for short?)—well, the result of that war was, I suppose, to confirm a number of long-term tendencies in United States history. It confirmed the Union; and, within the Union, it confirmed the ascendancy of the North and, still more, of the northern way of life. This northern way became, in fact, the United States way, except in the Old South—and, even there, the northern way was gaining ground. Other features in the landscape, too, remained unaltered. The foreign policy of the United States was still Washington's and Monroe's; if, at the turn of the century, anyone had forecast Wilson's and Franklin Roosevelt's foreign policy, he would not have been believed; if he had forecast Truman's and Dulles' and Kennedy's foreign policy, he would have been thought to have gone out of his senses. At the political level, the policy was one of self-insulation: no entangling alliances for the United States with European powers; no interference by European powers in the American hemisphere.

This policy of self-insulation was not, of course, thoroughgoing. Even on the political plane the phobia of foreign entanglements did not, if I am right, ever inhibit this country from entangling itself across the Pacific. For instance, the Spanish-American War did not arouse in American minds those misgivings and repinings that followed American participation in the First World War. Moreover, the shrinking from European entanglements was the American reaction to political European entanglements only. The people of the United States never thought of disentangling themselves from Europe eco-

nomically. The United States achievement of political independence did not check the growth of her transatlantic trade; and, throughout the nineteenth century, European capital and labor were the instruments that the United States used—and used without stint—for developing the resources of her immense national domain. The inflow of European investments and European immigrants in the nineteenth century enabled the American people to win the West. If the United States had not continued to draw upon Europe's resources in these two ways, I dare say the frontier of settlement might not, even yet, have reached the Rio Grande and the Pacific Coast. We might have been meeting here today to celebrate the laying of the foundation stone of Rice University, instead of celebrating the University's jubilee year in these splendid buildings.

Economic relations are, of course, by their very nature, a two-way system of communications. The nineteenth-century United States was an underdeveloped country; but unlike some of the countries that are still in this stage today, the United States did always pay her way; and the means of payment that she found produced economic repercussions in the home countries of her European creditors. Europe's first experience of the United States economic power was the flooding of Europe with cheap American wheat in and after the 1870's. This was a boon for Europe on balance. It brought timely economic relief to the rapidly growing population of Europe's industrial cities, but it depressed the standard of living in the European countryside. In Britain, this remained depressed till the Second World War. Denmark met the same agrarian crisis with greater intelligence and energy. She met it by going over from mixed farming for home consumption to skilfully managed specialized agricultural production for export. But, in one way or another, most European countries' lives were affected by those massive imports of American foodstuffs from the 1870's onward. This was an indication of the importance of the role that American economic productivity was going to play, first in Europe and then all over the world, in the half-century of the world wars.

What would have been the picture of the United States that would have been painted for me in 1912 by her own citizens if, in 1912, I had been traveling in the United States and not in Greece? It would, I believe, have been much the same—put in less simple-minded terms—as the picture of the United States that I was actually given in Greece in that year. Americans too, I fancy, would have depicted the United States in 1912 as being a Promised Land for wanderers in the European wilderness. Here, they would have told me, was a country in which ex-Europeans could make a new start with a fairer prospect.

By crossing the Atlantic, they could jump clear of the old evils of Europe. They could escape from Europe's inveterate follies and crimes: the senseless European international power game; the burden of competitive armaments and the bloody and destructive wars which this power game made inevitable; the political oppression of subject nationalities and of liberal movements by reactionary-minded governments; the economic oppression of tenants by landlords and of workers by employers. Here was a country where every man was his own master. Americans describing the United States in 1912 could cite, as witnesses, a host of American citizens whose grandparents had taken refuge in the United States from the famine in Ireland in 1846, and from the repression of the revolution in Germany in 1848, and from half a dozen other nineteenth-century European calamities and atrocities.

This pre–world-wars self-portrait of the United States was, I should say, true to life as far as it went, but I can think at once of two features of nineteenth-century American life that it left out.

This picture portrayed the United States as being unaggressive and unoppressive by comparison with contemporary Europe. Yet there were witnesses who would have given a different report: for instance, the survivors of the American Indians, the grandchildren of the Mexicans of the generation of 1846, and the tardily emancipated descendants of the Negro plantation slaves. These had been victims of the United States, not of any European power; so, for them, the United States would have been the symbol of colonialism, imperialism, and economic and social injustice. The war that the United States made on Mexico, and the sweeping annexations that followed it, were, in fact, a classical example of imperialism. The War between the States was the greatest and most bloody war of any in the nineteenth century anywhere. The abolition of slavery in the United States in 1863 was anticipated by the abolition of serfdom in Russia in 1861; and, compared with the American slave's lot, the Russian serf's lot had been an enviable one.

The sad truth is that the Europeans who had colonized the Americas had brought Europe's evils with them to the New World; and this is not surprising. An Atlantic voyage—even a slow and painful one in a small sailing ship—is not a cure for original sin. One cannot jettison in the ocean the burden that Bunyan's Pilgrim carries on his back. The Roman poet Horace lived to learn this salutary truth. Horace grew up in bad times—times not unlike these last fifty years of ours—and in an early poem he played with an escapist fantasy. He imagined some nonexistent western isles of the blessed for which he and his fellow Romans could set sail and so leave their civil wars

behind them in Europe. In later life, Horace came to know better, and then he wrote the memorable line: "Caelum, non animum, mutant qui trans mare currunt."[1] "One changes one's clime only, not one's character, by scudding across the sea."

Another feature of nineteenth-century American life that the conventional pre–world-wars picture left out was the part played by religion. One of the things that the European colonists in the New World brought with them from the Old World was their previous religion; and they would have been horrified if it had been suggested to them that they must make a break with that if they were in earnest about their program of making a new start in life on new ground. So far from that, the colonists and their descendants and the many generations of immigrants who have followed in their wake have always cherished their Old World religion. Indeed, the motive that led some of the most notable of them to pull up their roots in Europe and to cross the Atlantic was a wish to remain faithful to their European religion without any longer being penalized on this account, as they had been penalized at home.

However, deep down, there is a contradiction between the ideal of Americanism and the ideal of Christianity on the question of what one's relation with one's neighbor ought to be. One of the aspirations of Americanism was to insulate America from the rest of the world in order to turn America into a local earthly paradise whose citizens should be "not as other men are." One of the aspirations of Christianity is to "preach the Gospel to every creature," including all the publicans, harlots, and sinners. Christianity, like Islam and Buddhism, is a missionary religion; and, like them, it is this intrinsically, in virtue of its fundamental beliefs and ideals. Christianity's world-wide mission, like theirs, is part of the religion's essence; and therefore it is ultimately incompatible with sectionalism on any level—spiritual, political, or economic. The nineteenth century saw the emergence of a small band of Americans who were Christians before everything else, and who therefore recrossed the Atlantic to preach Christianity in the Old World.

At the time, these nineteenth-century American missionaries did not attract much attention. To friendly American eyes their deliberate rejection of economic opportunities at home seemed disinterested, no doubt, but quixotic. To unfriendly eyes their conduct may have seemed un-American. To re-migrate from the American earthly paradise to the Old World wilderness came near to being an act of treason against the Promised Land—just as a whale might seem to an elephant to be a traitor to the order of Mammalia for having slithered

[1] Horace *Epistulae* I. Ep. 11, l. 27.

back off the good dry land into the primordial ocean. Viewed in retrospect today, the nineteenth-century American missionary movement looks a good deal more significant. It looks like a premonition, through religious faith, of a truth that the present generation in the United States has been learning, with pain and grief, through harsh experience. This truth is that our social obligations to our fellow human beings have no limits short of embracing the entire human race. Mankind is a single family with a single destiny, for weal or for woe. In the Atomic Age, which mankind has entered in our lifetime, and in which our descendants will have to live so long as the human race lasts, a recognition of the human race's solidarity is one of the necessary conditions for the race's survival. All honor to those nineteenth-century American missionaries who recognized this truth so far in advance of most of the rest of us, and who had the faith, courage, and sincerity to stake their lives on acting in accordance with their spiritual insight. They were led to this act of self-sacrifice by their religion, and they dedicated their lives to it.

Christianity's recognition of the brotherhood of all men is a warning that a sectional earthly paradise is an unsatisfying spiritual ideal. There were more prosaic warnings that it was also not going to be a practicable objective. At about the time when Rice University was founded, Blériot flew across the English Channel in a mechanically propelled heavier-than-air conveyance, and, by then, Rutherford was already at work on exploring the structure of the atom. These were the first steps toward the forging of the annihilating intercontinental weapons that our governments now hold in their hands. By the same date a change was taking place in the balance of power in Europe, and this change was going to make the United States traditional foreign policy of avoiding entanglements in Europe no longer adequate as a means for keeping the United States secure in her own hemisphere.

From the date of Britain's recognition of the United States independence down to the rise of the Second German Reich, the United States policy of political self-insulation from Europe had been underwritten by British policy backed by British sea power. It was, I suppose, a happy chance for America that, during Britain's century of world power, Britain had the means, as well as the will, to prevent any single continental European state from gathering up the resources of the whole of Europe into its own hands and using them for conquering the world. When Napoleon was pursuing this aim, the United States did not have to bother much about him and his ambitions, because Britain—of course, entirely in Britain's own interest—was standing between Napoleon and her. In fact, Napoleon had to sell Louisiana cheap to President Jefferson, because British sea power made it im-

possible for France to take delivery of Louisiana from Spain. Britain could prevent Napoleon from pocketing New Orleans, but she had not the strength to wrest it out of its American purchasers' hands, as the British discovered by trial and error in 1814.

This post–Revolutionary War international situation was a godsend for the United States. It enabled her, for nearly a century and a half, to devote all her energies to the development of her own continent—all those energies, that is to say, that she did not spend on her Civil War. But international relations are kaleidoscopic. Each successive balance of forces is precarious and short-lived. Before the close of the nineteenth century, Britain's singlehanded predominance in the world was being undermined by the rise of a united and industrialized Germany. By 1914, Britain's predominance was already a thing of the past. In the First World War, Britain, France, and Russia combined were not a match for Germany. And Germany would not have been defeated either in the First World War or in the Second if the United States had not, each time, eventually thrown her by then enormous weight into the anti-German scale of the trembling balance.

In intervening militarily in both world wars, the United States was, I believe, taking action that was indispensable for the preservation of her own independence. If she had allowed Germany to win either war, Germany would have gathered into her own hands the control over the resources of the whole of Europe and Russia, and then surely nothing could have stopped Germany from subjugating the rest of the world, including the United States. The united resources of Europe are still the biggest potential power unit in the world. This is evident today, when western Europe is in process of uniting peacefully, by voluntary agreement, for the first time in her history. A union imposed forcibly by one European people on the rest always did, of course, arouse strong resistance, and always would arouse it. Yet, if Germany had won either war, she could have quelled the European resistance movements and then have used Europe's resources—including the colonial empires of the western European countries—as instruments for further conquests. The United States had, and still has, an Achilles' heel in Latin America. Latin American nationalism, social injustice, and natural resources are an explosive mixture. There is enough fissionable material here to blow up the whole Western Hemisphere. And a victorious Germany, once master of the Old World, could have stalked the United States by making her approach to the Western Hemisphere via the bulge of west Africa and the corresponding bulge of northeastern Brazil on the American side of the Straits of Dakar.

If I am right, the threat to the United States from Germany in both

world wars was serious. Yet, as far as I can make out, the American people did not take this serious German danger to heart—not even after they had found themselves compelled twice over to go to war with Germany in order to prevent her from subjugating the world, including the United States itself. I find this puzzling, and I do not know what the explanation is. If, since the end of the Second World War, the American people had not taken the Russian threat to the United States seriously either, I should have concluded that American minds had been conditioned by the international security that the United States had enjoyed from 1783 to 1916. I should have supposed that this conditioning had gone so far that it had almost become a psychological impossibility for American minds to entertain the idea that their country's security might really be threatened. This theory, however, is ruled out by the sensitiveness and the vehemence of the present American reaction to the Russian threat. This makes the previous American complacency about the former German threat mysterious. For, in each of the two world wars, the German danger was, I should judge, much greater than the Russian danger is—or, at any rate, than it has been so far. The Germans are a great deal more efficient than the Russians are, and therefore, when the German people dedicates its efficiency to the cause of war and conquest, the German danger for the rest of us is extreme. Thank goodness that, since the end of the Second World War, the Germans have been employing their immense practical abilities for peaceful and constructive ends. We may perhaps venture to hope that the Germans have been permanently cured of their militarism by their experience in the Second World War, as the French were cured of theirs by their experience in 1870. This lies on the knees of the gods, and, at the moment, I am concerned, not with speculations about the future, but with a matter of what I believe to be historical fact. My point is that, apparently, the American people did not take the German danger seriously in either of the world wars; and, if this is indeed a fact, it is one that has had unfortunate consequences for the United States and for the world.

The immediate consequence was that, as soon as each world war was over, the American people found themselves wondering, each time, why they had taken the part that they had taken, and resenting that they had done what they had done. After the first war they wondered why they had been at war at all. After the second war they wondered why they had not fought the Russians instead of fighting the Germans. Their action was now an accomplished fact. It could not be undone. But the United States could, and did, give vent to her

postwar sense of disillusionment by taking a number of momentous steps.

Let me remind you of some of the steps that she took between the end of the First World War and the beginning of the Second. She refused to join the League of Nations, which had been founded largely on the initiative of the President of the United States. She throttled the flow of European immigration by passing the immigration restriction acts of 1921 and 1924. She tried to collect her war debts from those European countries that had been her wartime associates. And then, when the coming Second World War loomed up, the United States enacted the neutrality legislation.

These interwar American acts were all disastrous for Europe. The restriction of emigration to the United States hit Europe at the very moment when Europe needed this outlet more than ever before. Imagine the effect on those Greek emigrants to the United States, who were giving me such a glowing account of the United States in 1912, if they had been told that, within less than ten years from then, the American people were going to partially close down immigration for the future. My Greek informants' praises of the United States would, I believe, have died on their lips.

I have often thought, since, of the number of young Europeans who, in the interwar period, might have become good American citizens if they had been given the same chance as their prewar predecessors. The Germans, in particular, have usually made first-rate American citizens. I wonder how many young Germans who turned Nazi might have taken this happier alternative course if it had still been open to them.

Perhaps Hitler would never have come into power if he had not had, ready to hand, a host of these frustrated and therefore restless and bitter young Germans for him to use for his evil purpose. Perhaps Mussolini would not have come into power either. I remember how, passing through Rome at the end of the year 1920, I was disturbed at the sight of swarms of demobilized but unemployed Italian soldiers lounging about in the uniform of the so-called Guardia Regia. These were potential Italian emigrants to the United States who actually became Fascists instead a year or two later. If these unfortunate, misguided young Europeans had had the opening in the United States that their parents' generation had had, I believe they would have led lives in this country that would have been useful to the United States and to the world, as well as to these young people themselves. In giving them the chance that she had given to their fathers, the United States would have been continuing to fulfil her own traditional ideal

of being a Promised Land. Instead of that, these wretched young Europeans became criminals and cannon fodder.

This was one tragic sequel to the First World War. Its financial aftermath was another. If, in this war, there had been lend-lease instead of war debts, and if, after the war was over, there had been a Marshall Plan instead of reparations, the world's history in our lifetime might have taken a different turn.

The tragedy of what happened after the First World War was equalled by the irony of it. For the steps taken by the United States produced exactly the opposite results from those at which she was aiming. The American people were homesick for their prewar past. They were determined never to let their country be drawn into a European war again. They had allowed themselves to be entangled for once, in spite of Washington's warning. Their reaction was to cut themselves loose again from Europe, and this time to do this thoroughly. They were going now to insulate themselves financially and economically, as well as militarily and politically. The effect of their action was to make another world war inevitable, and this made it also inevitable that the United States should once again become a belligerent. This, too, was inevitable because, in the Second World War, as in the First, the consequence, for the United States, of maintaining her neutrality till the war had ended in a German victory would have been to expose United States security to a risk that the American people were not prepared to run. Therefore, once again, the United States was bound to intervene when it came to the point of either intervening or letting Germany win.

Though the United States was thus certain to intervene in a second world war if Germany were to start one, neither the American people nor the Nazis seem to have foreseen this. The American people believed that, this time, they had made sure of being able to keep out. By refusing to join the League of Nations they had kept clear of political entanglements that might have involved them in war with Germany. By enacting the neutrality legislation they had insured themselves against the possibility of being drawn into war with Germany by economic entanglements with Germany's opponents. This was supposed, by one school of American historical thought, to have been the main cause of the United States involvement in the First World War. The Nazis, on their side, correctly interpreted these interwar American actions as being evidence that the American people were determined not to go to war with Germany again; but they shared the American illusion that the United States would actually find herself able to do what she wished. Both the Nazis and the Americans seem to have overlooked the truth that, in a world that is

divided politically into a number of sovereign independent states, each of which intends to try to preserve its sovereign independence at all costs, this will, in the last resort, be the governing consideration for every country. Even the most pacific-minded people will go to war if and when it finds itself confronted with a choice between going to war and losing its independence.

If the American people had foreseen this from the start, perhaps they would have joined the League of Nations after the First World War and have made military alliances of the NATO type with the west European powers instead of enacting the neutrality legislation. If the Nazis had realized the same truth, perhaps Hitler would have refrained from going to war, even though the United States had taken the steps that she did take with a view to keeping out. If Hitler had recognized that the United States would not be able to keep out, however much she wanted to, he would surely have kept the peace; for a would-be aggressor does not launch his war of aggression if he knows in advance that he is bound to be defeated. Hitler, of course, made war in 1939 in the belief that he was bound, not to lose, but to win; and this belief was reasonable on the mistaken assumption that the United States would be able to keep out. Germany would have won the First World War if the United States had kept out of that; and she would have won the Second World War as well if, this time again, she had had only France, Britain, and Russia in the field against her.

The United States took momentous steps after the Second World War, too. No more than seven years elapsed between the enactment of the United States neutrality legislation in 1939 and the proclamation in 1946 of the Truman Doctrine, placing Greece and Turkey under the United States aegis. Is there any other instance in history of such a dramatic reversal of policy within so short a span of time? Even after the United States had become a belligerent in the Second World War, she had refused to entangle herself in any military operations in eastern Europe and in the Levant—as if this was going to make any difference, now that she was thoroughly entangled with western Europe, northwest Africa, and the western Pacific. In still shunning entanglements in the eastern Mediterranean, the United States was trying to cling to a last shred of Washington's policy. The neutrality legislation of 1939 had been a supreme effort to maintain that policy intact in an international situation in which it had become manifestly impracticable since 1916. Since 1946 the United States has thrown her time-honored traditional policy to the winds and has adopted a new policy that is the exact opposite of it.

In the past, the United States sought to avoid clashes with other

powers by drawing in her horns and withdrawing into her shell. Since 1946 she has risked clashes with the Soviet Union by rushing forward to meet and stop her adversary as near as possible to his frontiers and as far as possible from her own. Not only in Turkey and Greece, but in the offshore islands, in Laos, in Berlin, the United States has dug herself in at the very foot of the Communist world's ramparts. Before 1946 the United States shunned alliances; since 1946 she has been seeking them. During the interwar years, Britain and France longed wistfully for the unobtainable alliance with the United States—an alliance that would have been the one effective deterrent to a Germany that was meditating a war of revenge. Since 1946 it has been the United States who has been anxious to gain and keep allies, while Britain and France, in their weaker moments, have sometimes wondered whether their alliance with the United States is not a more dangerous entanglement for them than they can afford. Before 1946 the American people believed that the international power game was a crime and a folly that was peculiar to the depraved nations of the Old World. Today the United States is playing this very power game herself. She is playing it with all her might, and this on a worldwide scale. There is no patch of the habitable and traversable surface of the planet, however remote and however barren, that the United States does not now feel to be her concern if it is a question of forestalling Russia in gaining a foothold there.

The reversal of the United States foreign policy on the political and military plane has been extreme. The reversal of it on the financial and economic plane has gone to equal lengths. During the Second World War, lend-lease was substituted for repayable loans to the United States associates. After this war, when Europe's economic life was at a lower ebb than it had sunk to after the first war, the United States did not again leave this European wasteland to produce another crop of noxious political weeds like fascism and nazism. She launched the Marshall Plan. At her own expense, without asking for any economic return for herself, she gave the exhausted and impoverished European peoples the means of recuperating. The Marshall Plan is the cause of western Europe's present prosperity; and eastern Europe could have been proportionately prosperous today if Russia had not prevented the eastern European states that were under her domination from accepting an American offer that had been extended to them as well. Today one of the most constructive of the economic and political movements that are taking place in the world is the movement toward European union. This is a movement that has no precedent in European history; and its origins, too, can be traced back to the Marshall Plan. American aid stimulated the western European

peoples that received it to co-operate with each other for using it to the greatest common advantage. I believe the temporary European organization for implementing the Marshall Plan was the germ of the permanent European union that is now coming into existence.

The contrast between the United States reactions to the two wars is extraordinary. Her reaction after the first was a desperate effort to retreat again into the isolation that she had enjoyed in the preceding chapter of her history. Her reaction since the second war has been a resolute acceptance of the hard fact that, in the world as it has now come to be, isolation is no longer possible. The American people have, in fact, recognized and accepted the truth that, for the United States, the age of isolation is now over. This change in the American people's outlook corresponds accurately to the change in their position in the world. It is, I should say, the most epoch-making event in the history of the United States since the achievement of independence.

How are we to appraise this stupendous change of orientation? Looked at from one point of view, it is a tragedy. The American people's immense, and immensely successful, exertions throughout the nineteenth century were largely inspired and stimulated by the ideal of building up in the New World an insulated earthly paradise, uncontaminated by the Old World's ancient evils. This long cherished American ideal has now been proved, by merciless experience, to have been an unrealizable dream. The Old World, whose dust the Americans believed that they had shaken from off their feet, has closed in on the American New World and has engulfed it. The Americans have discovered that they have to reconcile themselves to living in the Old World after all. For any people, anywhere in the world, at any time, so complete a disappointment of such fundamental hopes and expectations would have been a tremendous ordeal. The shock caused by it is bound to be great. This is inevitably a painful episode in United States history, but happily it has another aspect besides the tragic one.

To be rudely awakened from an agreeable dream is a tragedy that brings a reward with it if one is able to rise to the occasion; and the American people have risen to this occasion, I believe. Being awakened means being recalled to realities; and after the second war the American people have done, I believe, what they recoiled from doing after the first war. They have now recognized the realities of their situation, and have accepted them; they have faced them clear-sightedly and resolutely; and, being Americans, they have taken action. Obviously the United States action since the Second World War is not beyond criticism. No human action ever is. But, at least, the American people

have taken note of their previous mistakes and have taken care not to repeat them. Such self-criticism and self-correction is all too rare in human affairs. When it is achieved, it is a sign of spiritual strength and maturity, and it gives promise of future success. For instance, the United States has not, this time, repeated, for herself and for Russia, the mistake that she made during the interwar period for herself and for Germany. This time she has not allowed either herself or a potentially aggressive foreign power to be under any illusion about what the United States would do if this other power did launch a war. The United States has made it unmistakably clear that, this time, she would not only be a belligerent but would be at war with the aggressor from the start.

To be thus reinvolved in the international power game is, of course, a terrible plight to be in. It is doubly terrible when it is a disappointment of long-standing previous hopes and expectations. It is utterly terrible when it happens, as it has happened to the United States, at a moment when the invention of the atomic weapon has made the evils of war incomparably worse than they have ever been in the past. In such circumstances, it is only human that Americans should sometimes look back wistfully to the antediluvian age of isolation. This is human, but it is unprofitable, I think. Before one allows oneself to hanker after a lost isolation, there are two questions about it that one ought to ask and answer. The first question is: Was isolation ever a practicable policy for the long run? The second question is: Even if it had been practicable as a permanent policy, is it a good policy intrinsically?

I myself believe that the answer to both questions is a negative one. I believe that, from the beginning, the self-insulation of the United States was a wasting asset. By the time when Washington sounded his warning against foreign entanglements, the Industrial Revolution was already under way; and the Industrial Revolution, once started, was bound to result in "the annihilation of distance" and in the consequent transformation of the whole surface and the whole air-and-space envelope of this planet into a single arena for atomic warfare, if the international power game should ever take the form of war again. This is the most fearful situation in which we human beings have ever found ourselves since the date when we established our ascendancy over the other wild beasts. As we sit at the feast that modern technology has served up to us, another product of modern technology, namely the sword of Damocles, hangs suspended over our heads. Today the whole human race is exposed to this threat of self-annihilation; and in this age the American people could not have

contracted out of this common human predicament, however desperately they might have clung to their vanishing isolation.

The second question cuts deeper. This question is whether it would have been a good thing for the American people to continue to enjoy a privileged position, supposing that this had been feasible. It might require some spiritual effort to give a negative answer to this question, too. Yet I fancy that this is the answer that most Americans would give it today. The price of being privileged is to be lonely and unloved; and this is too high a price to pay for anything. Privileged persons or nations cannot even love or admire themselves. At any rate, they cannot do that with any convictions if their ancestral religion is Christianity. What Christ stands for is God's deliberate renunciation of his privileged aloofness. Christ stands for a voluntary participation in the suffering that is the creation's common lot. If Christianity means anything to us, it means that we must try to follow this example as best we can.

Since we are only human, our best efforts will be likely to fall far short of the Christian standard. Like the American missionaries in the nineteenth century, the whole American people in our postwar age has deliberately stepped out of its transatlantic earthly paradise and has re-entered the Old World. So far, so good. But there is a difference in the objectives. The missionaries re-entered the Old World in order to propagate Christianity there. The present generation of Americans has re-entered it in order to check the propagation of communism there. Both objectives are legacies from the American people's European past. "Caelum, non animum, mutant qui trans mare currunt." America's European heritage is, however, a mixed bag. The power game, as well as Christianity, is part of it. The Pilgrim who made the passage of the Atlantic believed that he had put off the Old Man in taking leave of Europe and that he had put on the New Man in setting foot on America's virgin soil. The reversal of the United States traditional foreign policy in our day has shown that the Old Man had not really been put off; he had merely been put to sleep; and now this sleeping spirit in the American soul has been sharply reawakened.

Who is it that has reawakened it? What Hitler failed to do to America was done to her by Stalin. Hitler presented a threat to the United States without making her aware of the peril that she was in. Stalin made her intensely alive to the peril of his threat, though, as I, for one, see it, the postwar Russian danger for the United States was not, and is not, comparable to the previous German danger in real magnitude. Why, then, have the American people taken the Russian threat so much more to heart? What accounts for the differ-

ence between the respective American reactions to these two threats?

The answer to this question is not to be found, I believe, in any differences between Nazi Germany and Communist Russia. The differences between these two totalitarian powers are many and great and important, but I do not believe that the explanation of the change in the American people's attitude lies here. I believe it lies in a change in the American people's own attitude and outlook.

One cause of the vehemence of the American people's reaction to the Russian threat is simply the fact that, for some reason, it was Stalin and not Hitler whose aggressiveness made America aware that her traditional policy of self-isolation was now bankrupt. One may not be sorry to have been awakened from a dream—painful though the awakening may have been—but one does not feel grateful to the person who has jolted one back into a wide-awake consciousness of the real world. This is a well-known story. The patient is seldom grateful to the psychotherapist by whom he has been cured. There is, however, perhaps a second cause of the present violence of the American reaction to the threat from Communist Russia. Let me put this possible other cause to you tentatively. I am conscious that here I am treading on particularly delicate ground. What I have in mind is a change which I fancy that I have observed in the American attitude to life.

The American people started life as a revolutionary people, and this long before they won their political independence in the Revolutionary War. The initial act of leaving an ancestral home in Europe and making a fresh start in the New World was a revolutionary step; and some of the first settlers on North American soil were people who had made their European home too hot to hold them by taking a previous revolutionary step. They had broken with their European native country's local established form of Christianity; and one of their motives in crossing the Atlantic was their wish to be free to follow their own nonconforming Christianity in their own way. The American people thus have revolution in their blood, and this is their own traditional picture of themselves. Moreover, this American self-portrait used to govern the American people's attitude toward their fellow human beings in the Old World. American policy of non-involvement did not carry with it a suspension or repression of sympathies and antipathies. Even in their most isolationist moods, the American people have been hostile to Old World tyrants and oppressors and have been sympathetic to these tyrants' victims.

No doubt, the American people see their present quarrel with Communist Russia in these traditional terms. A belief that, in opposing Communist Russia, they are taking the traditional American stand is, I fancy, one of the convictions that is giving the American people

confidence in the righteousness of their present-day cause. The communist regime in Russia is unquestionably oppressive and tyrannical, but that is not all that there is to be said about it—as it was all that there was to be said about the Nazi regime in Germany. Communism is a tyranny that stands, paradoxically, for economic and social justice as against vested interests. Its performance evidently falls very far short of its principles; indeed, it sometimes seems positively to belie them. Yet these principles remain inscribed on communism's flag; and, even if the Communists are untrue to them, the principles themselves are a potent force in the present-day world.

They are potent because they express the aspirations of the huge depressed majority of the human race. This majority cares, I believe, for equality more than it cares for liberty; its objectives are economic realities, not political abstractions. It wants the bare necessities of life, because it lacks even these. It is becoming aware that modern technology can supply its elementary needs, and it is therefore becoming impatient of its age-old poverty. In the eyes of the poverty-stricken mass of mankind, the enemy is the vested interests of the rich minority. And this brings us to the difficulty in which an undiscriminating opponent of communism finds himself. In opposing communism intransigently, it is difficult to draw a line between opposing its tyranny and oppressiveness and opposing all its works and all its principles alike. Its is therefore difficult to avoid slipping into the position of opposing economic and social justice and championing vested interests. Anyone, however, who does slip into this position may find that, without intending to, he has alienated the poverty-stricken majority of mankind. This majority knows little about the Communist and anti-Communist ideologies, and perhaps cares less about the little that it does know. But it cares immensely about the social justice for which communism professes to stand. For this reason, an undiscriminating attack on anything and everything that communism stands for is likely to have the incidental effect of making the mass of mankind feel a solidarity with communism. It may, in fact, incline them to come down on communism's side.

Therefore, I should say that when we, the rich minority, are opposing communism, we ought, all the time, to be searching our hearts. We ought to make sure that we are opposing communism for the right reason only. The right reason for opposing it is the reason for which we opposed the Nazis. It is right to oppose tyranny and oppression, wherever we encounter them. We must always remember, however, that we are exceptionally rich, and that we are therefore exposed to all the temptations that riches bring with them. We must remind ourselves of the repeated warnings in the Gospels about the

snares in the path of the rich and about the special difficulties in the way of their finding salvation. If we ever catch ourselves opposing communism, not in defense of its victims, but in defense of our own vested interest in the preservation of our own wealth, we ought to take that as a danger signal and to draw back. Is our island of prosperity in the West to be a Promised Land for the poverty-stricken majority of mankind? Or is it to be a privileged minority's closely guarded preserve? Have we ascertained what is the genuine answer to this question in our heart of hearts? We cannot afford not to search our hearts for the true answer. Whatever the true answer may turn out to be, it will be decisive for the future of the United States and the West and the world.

I have mentioned the dramatic *volte-face* in the foreign policy of the United States. Since 1946 she has veered round from her traditional policy of keeping out of the international power game to a policy of involvement in it up to the hilt. There has, I believe, been a no less extreme and dramatic change in the domestic social structure of American society. The Constitution, as I read it, was intended to serve a community of citizens who were their own masters in every field of activity—in the economic and religious fields, for instance, as well as in the political field. The American community that was in the Founding Fathers' minds was a community of farmers who owned their own land, of traders who owned their own store and stock, and of professional men who were self-employed. How many of us are still self-employed in our present-day Western world? We have bigger real incomes than our forefathers, but these come to us, nowadays, largely in the form of wages and salaries. In other words, we have been buying our present prosperity by trading away some of our ancestral freedom, and I do not believe that this has been a good bargain.

When one adds these changes, within the last half-century, in the United States domestic life to the contemporary changes in her relation to the rest of the world, the total amount of change is staggering. In this flux, is there any guideline to which we can hold on?

Well, I come back, in conclusion, to my first introduction to the United States, which I described at the beginning of this talk. What was it, in 1912, that made those Greek emigrants to the United States, whom I met in their home villages, so enthusiastic about the country of their adoption? The thing about the United States that had struck their imaginations and had won their hearts was the American people's generosity. Here was a people that had crossed the ocean to carve a new world out of the wilderness; and, when, by the pioneers' hard labor, the wilderness had been transformed into an earthly paradise,

the people who had created this paradise were not trying to fence it in as a close preserve for themselves. They had thrown it open for other needy Europeans to come and share it with them. Every Greek immigrant had tested this American generosity by personal experience. His praise of America was praise of this American virtue in particular. I also come back to those nineteenth-century American missionaries. Their treasure was a spiritual one; and they were ready to renounce the material treasure that was within a nineteenth-century American's grasp in order to share their spiritual treasure with their fellow human beings in the Old World.

This American generosity is, I believe, characteristic of the American spirit. Anyway, it is a golden thread which keeps on shining out in the lengthening skein of America's destiny. It shone out in Marshall aid to Europe; it is shining out again in the aid that the American people are giving today to Asia, Latin America, and Africa. Here, I should say, is something in American life that has suffered no change within these last fifty years. Here, as I see it, lies the hope for the future of the United States, and therefore also for the future of the world.

BRAND BLANSHARD

The Test of a University

"THE MOST SEARCHING QUESTION that can be asked about a university is, what sort of person does it produce? Of course, there are other things besides persons of quality that we may justly demand of it. It must pay due regard to the practical needs of its society and its students. Statesmen have reminded us of late that we are short of scientists and engineers, and that our universities must try to restore the balance. Students who propose to spend four years and some thousands of their fathers' savings in a university expect, not unreasonably, that it will contribute to their success in the economic battle, that, whether their lot in life is building bridges or pulling teeth or teaching a language, the university training should give them some claim to the title of experts. But range and expertness of product are not the crucial tests. The question of overriding importance for any university is, what sort of man walks out of its doors?"

That is the question we usually ask when we turn an appraising eye on educational systems other than our own. We look at the French system with its rigorous *lycée* training, its standardized courses, its national competitive examinations—a system very different from our own—and we wonder what to say of it. There would seem to be no way of judging it except by appraising its product. That may be a complex business, I admit. The French university graduate exhibits greater precision in his scholarship than our own, greater readiness and skill in expression, greater adroitness in intellectual fence. He is also said to exhibit a somewhat parochial insularity from anything non-French, a fierce individualism that produces for three Frenchmen four opinions and excludes political compromise, and an odd combination of intense loyalty to France with an invincible reluctance to pay his taxes. The German *Gymnasium* and university are both notably different from our own; the break between them is sharper, and

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it throws the advanced student more ruthlessly back on his own resources. Is the system better than ours or not? The decision again must rest on the product. The German graduate is probably more rigorously disciplined and highly specialized than ours, and perhaps intellectually more sophisticated. But two world wars have made plain that there was something amiss about him. The people who were supposed by themselves and others to be the best educated in the world capitulated with dismaying readiness to the leadership of cranks and dervishes. Russian education remains a puzzle to us. Its achievements in applied science have been spectacular, in some areas outstripping our own. But even if these achievements were greater than they are, we should probably still be skeptical about them. Why? Chiefly because doubts would still linger about the sort of man produced by the Soviet effort. Is he a mind that can play free in the humanities and politics as well as forge along in his specialty, or has he been living in a mental and political strait jacket that has ossified the cartilages of his mind? It is on the answer to this sort of question that judgment must be based in the end.

All this implies that we have in our own mind some view, however dim, of the kind of man an education should produce. And since, if I am right, this implicit ideal is the rod by which we must measure education, it may be useful to try our hand at sketching it. I do not know whether my own ideal figure will look like yours, and since he is too elusive and wraithlike to sit still for a portrait, I can only draw him from fugitive glimpses and hope he will be recognizable enough to allow you to accept or disown him.

Look at him first on the intellectual side. Here his chief characteristics will be two: he will have intellectual interest, and he will have sound judgment.

Interest

All of us are interested, and strongly interested, in some things—the broker in his stocks, the mother in her children, the stamp collector in his stamps. But outside the circle of these interests, awakened by utility or instinct or accident, our minds may be pretty bleak, so that when the broker talks to the mother or the stamp collector, both sit in uneasy silence, groping about for some common ground. There is a great difference, as Chesterton noted, between an eager man who wants to read a book and a tired man who wants a book to read. Breadth of interest is necessary even for the plain good citizen. How is one to vote responsibly with no interest whatever in foreign aid or foreign trade? How is one to give discriminatingly or play one's local part if one has no concern about public health, delinquency, housing,

hospitals, or schools? At present we are kept going by the interest in these matters of a fraction of the citizenry, who are of course the salt of the earth.

True intellectual interest will run beyond even these bounds. It will be the interest of a citizen of the world, eager to be at home in it, intrigued and invited by it not merely because the knowledge of it is useful, but because of the intrinsic fascination of exploring it, of understanding it, of watching its expanding frontiers. If our time is one of political chaos and a population explosion, it is also the time of an unprecedented explosion of human knowledge. This has shifted the center of educated interest in the direction of science. The Roman Terence thought nothing human alien to him, and this has been cited a thousand times by humanistic scholars as a model of breadth of vision, though it makes no mention of the world in which the physical scientist lives. Dr. Thomas Arnold, headmaster of Rugby, said: "Rather than have physical science the principal thing in my son's mind, I would rather have him think that the sun went round the earth, and that the stars were so many spangles set in the bright blue firmament." Sir Charles Snow has reminded us that we can no longer afford such indifference, and that unless we recover from it we may shortly be gathered to our fathers, with the Russians, who are far from indifferent, ruling in our stead. The educated man I am sketching needs no such reminders. The thought that the physical world he lived in as a boy has dissolved before his eyes and that matter itself has now become, to use Russell's words, mere "waves of probability undulating in nothingness" will carry an excitement of its own. I am not suggesting that he will be interested only or even chiefly in science; revolutions have been going on not only in men's theories of nature but also in their views of human nature and of the supernatural. William McDougall said of Freud that he had contributed more to psychology than any man since Aristotle; and Karl Barth has changed the theological climate of Protestantism. It does not detract from the interest of these two figures to realize that if one of them is right, the other must be wrong; there is a special fascination in the conflict of such gladiators. The person who is bored in the modern world shows that he is in no full sense a member of it.

Judgment

The second characteristic of the educated mind is sound judgment. Can we say anything useful about such judgment generally, whether displayed in business, law, or morals? Yes, I think we can. It seems to have two chief bases. The first is reflectiveness, in the sense of a settled habit of seeing things in terms of their consequences. It is

the opposite of impulsiveness; it is the trait of the man who looks before he leaps, and trims his plans and beliefs to accord with his prevision. Good judgment in chess requires the foreseeing of what a move will probably entail on the part of one's opponent; good judgment in a businessman requires a sense of what will happen if he moves his store to a new site, or cuts his prices, or raises his wages; good judgment in mathematics or philosophy requires that the thinker see any theory proposed to him in the light of its implications. Military strategy is a particularly good field in which to study what good and bad judgment mean, since the moves and their results stand out so clearly. Field Marshal Lord Wavell once prepared a list of the great commanders of history, based upon their ability to take into account all the factors, military, personal, and political, on which decisions should be based. It surprised many. The meteoric Napoleon stood sixth on the list. First came Marlborough, the embodiment of versatility, then Belisarius, the great Byzantine of the sixth century, then Wellington, Frederick of Prussia, and Lee, distinguished even in defeat. All were masters of the sort of prevision that suited imperfect means to large ends.

Now this capacity to see things in the light of their consequences may itself have different bases. Sometimes it is mainly a gift of Providence. Whatever the doctrine that all men are born equal may mean, it does not apply to their intelligence; imbeciles and geniuses are born, not made. Some minds can see effortlessly and at once how to solve an equation, how to escape from a maze, what to do about a fire or an accident, while others with a like experience behind them have to sit down and think it out. These latter, who perhaps include most of us, have the other kind of intelligence, which is based on effort and habit. They may go farther in the end than competitors with a higher I.Q., for what is commonly called intelligence is very largely character. A normal person can make himself intelligent in this very important sense by discipline; indeed, the providing of this discipline is the main work of higher education. Such intelligence is far more important than knowledge. Mere catholicity of interest may fill one's mind over the years as full of information as one of our government granaries is full of surplus grain and with as little profit to the owner. What turns knowledge to account is the habit of trained reflection; Pascal said that most of the ills of the world were due to the fact that men could not sit in a room and think. If philosophy, as someone has said, is the process of thinking about everything else philosophically, we all need to be philosophers. And we all need to be scientists, not in the sense of being experts with computers or microscopes, but in

the sense that we have acquired the habit of observing things accurately, thinking about them, developing our thoughts into their consequences, and checking these against the facts. Indeed, good judgment in matters of fact *is* just scientific method converted into habit.

THE TRAINING OF JUDGMENT

No one academic subject is essential to this sort of discipline. Mathematics has often been put forward as the great whetstone of the mind, but work of much power and exactitude has been done by the mathematically incompetent—in archeology by Wallis Budge, in philosophy by F. H. Bradley, in history by Macaulay who, according to Sir Richard Jebb, "seems to have regarded every mathematical proposition as an open question, a theme for lively debate." History has often been thought the ideal educational subject as combining scientific with humanistic interests, but if we discovered that Darwin or Einstein were historically ignorant, would that affect our respect for what they did? I should be happy to plead the cause of my own subject, philosophy, but I should have admit that if that means the philosophy of the specialist as opposed to the reflective habit, most men get on pretty well without it; indeed, Emerson remarked: "Who has not looked into a metaphysical book? And what sensible man has ever looked twice?" No, trained and critical reflection has not been patented by any single subject, and a first-rate teacher can exemplify what precision, order, lucidity, and self-criticism mean in teaching anything from cytology to numismatics.

The fact is that trained intelligence is not only not the perquisite of any university subject; it may be achieved without any help from college or university. Science is common sense refined and rendered self-critical, and with sufficient dedication that refinement can be achieved by one's self. Samuel Butler said there were two great rules governing human life, a general one and a special one: the general one was that everyone could make of himself what he wanted to, and the special rule was that everyone was more or less an exception to the general rule. But it is well for us academics to remind ourselves occasionally that neither Washington nor Lincoln, neither John Stuart Mill nor Herbert Spencer, neither Franklin nor Faraday nor Edison, neither Marlborough nor his great descendant and biographer ever attended a university, that neither of the Wright brothers had so much as a high-school diploma. What is important, whether in a university or out of it, is the power to identify first-rate work when we see it, enthusiasm for it, and the appropriation of its standards in one's practice. If a young man clearly sees the quality of *The Wealth of Nations* or *The*

Origin of Species or the essay *On Liberty* and feels the urge to go and do likewise, he has the root of the matter in him; indeed, he has gained, whether by himself or not, the best thing that a university could afford.

JUDGMENT OF GOOD AND EVIL

I suggested that good judgment has two bases, one of which is the reflectiveness that sees beliefs and proposals in the light of what they imply. But there is a second element in good judgment, the sense of value. The first without the second has often been a menace to mankind; think of the intellectual power that German generals and scientists threw into the service of Hitler. There are lawyers of great gifts who are not above using them to smirch innocence and condone wrong. Some large American fortunes have been built on a well-mixed concrete base of shrewdness and callous inhumanity. Indeed, the commonest criticism of our culture as a whole is that it combines a large control of the means to the good life with much dimness as to what the good life is. If judgment is to be sound, it must be able not only to calculate consequences, but to weigh the good or evil of those consequences.

Now what makes experience valuable is the fulfilment and satisfaction of human needs. Some of our activities—the daily buttoning and unbuttoning, the routine of commuting to our work—are trivial, however necessary, because they do not realize our powers in any satisfying way, while others—the achievement of a new understanding or friendship, a new response to Mozart or Wordsworth—do somehow fulfil and enlarge us. We are sometimes told, of course, that there is no such thing as the really good or bad in art or morals, that it is all a matter of taste, and taste is arbitrary. This I disbelieve. There are some poems—for example, Gray's *Elegy;* some novels—for example, *War and Peace;* some plays, like the great Shakespearean quartet of tragedies, that are good by general suffrage; they are good because they speak not to something peripheral in human nature, but to its central interests and longings, because they help us to see ourselves in perspective and to be ourselves more fully.

Now the vision of good and evil calls for imagination, and this is why the humanities are so essential a complement to merely intellectual discipline. The humanities are the soil in which imagination grows. Authors in inventing Captain Ahab and George Babbitt, and we in understanding them, are trying out in idea varying ways of life, and because we have entered into them, we shall make our own future choices with relevant experience behind us. Many people, when they have rejected new adventures of the mind, have done so because they

did not know what they were rejecting; it is hard to believe, for example, that the Puritans in rejecting drama, or Mr. Ford in describing history as "bunk," really knew what they were forgoing; they were judging from too narrow a base. Many persons in our own society, which has the highest living standard ever known to man, have achieved wealth and efficiency over the years by hard, unremitting application, only to find at the top of the ladder an inward void, and to realize too late that the rigors of the climb have left them fitted for nothing but going on with the climb, however pointless now. This applies to the intellectual as well as the practical life. Scientists, whose techniques are becoming more technical and demanding, have realized that science is too thin and cerebral a diet for "human nature's daily food"; our medical and engineering schools are insisting that both as raw material and as products they want men, not high-powered human computers. "The Science of the nineteenth century," a British writer says, "seemed to expel poetry with a brandished test-tube; the Science of the twentieth re-opens the door to her with a bow."

Rationality in Practice

We have been looking at our ideal university product on his intellectual side, and we have found that he will have two marked traits, breadth of interest and good judgment, the latter resolving itself in turn into reflectiveness and the perception of values. Happily we can touch the nonintellectual side of him more lightly, since this is not the university's prime concern. It will be enough to say one thing: his emotions and his impulses will be under rational control. It is a strange fact that a towering genius may be an overgrown child full of tantrums, self-pity, and irrational hatreds. This sort of genius, though insufferable to live with, is more interesting to read about than mere dull reasonableness, and so much is made of it in print and on the screen that some young people have drawn a wrong inference about it. They have concluded that eccentricity is a part of genius, so that if one lives like Scott Fitzgerald or Dylan Thomas, one is showing some kinship with their creativeness. It does not follow. One is copying their weakness, not their strength. "Imagine the greatest man you can think of, in a bad temper," says F. L. Lucas. "Does he still, at that moment, seem great? No. Not even were he Alexander. Real greatness implies balance and control." Romantics do not like to admit this; "those who restrain desire," said William Blake, "do so because theirs is weak enough to be restrained." But one may restrain passion not because one feels less, but because one loves sense and reason more. And "it is by no means self-evident," as Mr. Eliot notes, "that human beings are most real when most violently excited." Education, on its

emotional side, is discipline in the art of adjusting feeling to its object. The only feeling excluded by this discipline is feeling that is ill-tempered or intemperate.

As for impulses, they too can be disciplined, for they are the raw material of an educated will. But universities can hardly undertake this sort of education, which must be turned over, for the most part, to the more ruthless school of life. Unhappily, a person who is both reflective and sensitive may be thoroughly flabby of will. A French writer said of someone, "Il pense comme un homme, il sent comme une femme, il agit comme un enfant." That could be said, I suppose, of many persons of stature—of Coleridge and De Quincey, for example, who for all their scholarship were ill-regulated and ill-disciplined characters. What wishy-washy creatures they seem by the side of the old Iron Duke, Wellington, who said, for example, that having found there was no point in lying awake, he never did. Universities cannot generate wills of this kind, but they ought not to discourage them, as I sometimes think they do. Men who earn wages or run a business have to keep themselves to their task and get things done on schedule; students often get by with a degree of self-permissiveness that would ruin them in an office or a regiment. The habit of seeing things through, of doing quietly and promptly what has to be done, is one that can be acquired, and whether acquired in a university or not, it is one of the marks of a really educated man.

Well, there is the rough picture of this man that I find in the back of my mind. Perhaps when he is thus sketched in the abstract, there will be little debate about him. Everyone nods assent to the suggestion that a life is better for breadth of interest, good judgment, and the rational control of feeling and impulse. But I should hope for more than the automatic assent to an abstraction. I should like to think that embodiments of this abstraction, if set before us in flesh and blood, would be really liked and admired. Do such embodiments actually exist? If so, we shall know better how we feel about the ideal I have been describing when we look at its incarnations.

Happily, there have been such people, not perfect examples, of course, or they would not be human, but at least instructive approximations to it. I will not take living examples, which are likely to be invidious, nor will I take examples from our own country, for the rather distressing reason that it seems harder to find here the kind of examples I want. My impression is that they would also be hard to find in Germany, though somewhat less so in France. Whether it is through ignorance, prejudice, or insight that my choice falls on England I am not sure, but the English universities do seem to have been more pro-

lific of the type than others I happen to know. This may be partly because the British universities skim a thicker cream off the general population than those of other countries, and partly because Britain, for all its residual class system, has a generous tolerance for marked individuality. But no doubt it is also due in part to the fact that the older British universities were founded and organized to turn out not merely "squares" but persons in the round. Let me name three men who were so nearly contemporary that they all knew each other and so nearly contemporary with us that I knew the first, saw the second in action, and might have known the third.

Three Examples

Gilbert Murray seems to me to offer about as good a pattern of the educated mind as one could hope to find. He was of course a scholar, so brilliant indeed that within about a year of taking his B.A. at Oxford he succeeded Sir Richard Jebb as professor of Greek at Glasgow. But more important than his knowledge of Greek was the fact that he *was* a Greek in mind and temperament. As a discerning friend said of him,

> he had, in a degree far exceeding that of most modern scholars or modern men . . . that central serenity and self-sufficiency . . . which [ancient philosophers] so commonly made it their object to attain. . . . I doubt if Murray ever acted, except on the spur of the moment—and such moments occur to every man—without first asking if what he proposed to do were just and considerate. This is the teaching of Greek moralists and indeed of Greek literature in general; *audi alteram partem* is characteristic of all their best writers, and is what enabled them to create Greek drama and science and philosophy. Murray was like them in this, that his appeal was always to reason and humanity. . . . He said at the end of his long life that for many years there had never been a day when he failed to give thought to two things: Hellenism and the work for peace. [British Academy, *Proceedings*, XLIII (1957), 256, 257, 254.]

Little by little it came to be recognized that the Regius Professor of Greek at Oxford was not only a rare spirit but a power in the land. He was made head of the League of Nations Union; he was the courageous president of the Society for Psychical Research; he was chairman of that Committee on Intellectual Co-operation that did so much to save the scholars of Europe in Nazi days; he served as Norton Professor of Poetry at Harvard and very nearly as British ambassador to the United States. Though an Australian by birth, he was awarded the Order of Merit as one of the greatest of Englishmen; though a ration-

alist in religion, he was buried (when he could no longer protest) in Westminster Abbey. He was a humanitarian as well as a humanist, and though the gentlest of men, had a passionate hatred for two things, cruelty and injustice. One passing remark of his I find revealing. He and Rudyard Kipling knew each other as boys, and indeed planned to write a huge epic together. In later years, a friend asked him how he liked Kipling. "Not very much," he answered; "I remember that he threw a stone at a cat."

The second man was a better friend of Murray's, and one whom he always revered: Herbert Henry Asquith. He too was a brilliant classical scholar who retained his interest in the classics to the end. But he was a Roman, not a Greek. He went into politics and proved more impressive in Parliament than he had been in the university, quickly becoming home secretary and then prime minister. Even among prime ministers he stood out, for the quality of his mind and character raised the level of British public life. He had "the best intellectual apparatus, understanding and judgment," said Lord Chancellor Haldane, "that I ever saw in any man." One of his inveterate opponents, Lord Birkenhead, after comparing him to no less a figure than Julius Caesar for his quiet, impersonal, universal adequacy, went on to say: "Mr. Asquith's character is a national asset. He fights cleanly, wins without insolence, and loses without rancour." It is natural enough that such a man should succeed as jurist, bishop, or professor, but that he should have preserved in the rough and tumble of politics the clarity of a logician, a style that was the admiration of scholars for its purity and economy, and a complete freedom from professional envies, personal animosities, and all the little vulgarities that are almost forced upon politicians, is amazing.

What is the secret of it? The answer is, I suppose, that in his case education really "took." In an address to university students he left on record what he thought a university should try to produce, and what his hearers must have thought it had produced at least once.

> It is not enough [he said] that a university should teach its students to eschew narrowness in the range of their intellectual interests and slatternliness in speech and writing. It should put them permanently on guard against the Dogmatic temper. . . . To be open-minded; to struggle against preconceptions, and hold them in due subjection; to keep the avenues of the intelligence free and unblocked; to take pains that the scales of the judgment shall be always even and fair; to welcome new truths when they have proved their title, despite the havoc they make of old and cherished beliefs—these may sound like commonplace qualities, well within every man's reach, but experience shows that in practice they are the rarest of all. [*Occasional Addresses*, pp. 94–95.]

Asquith was sometimes thought to be a human iceberg, a massive gleaming intelligence without feeling. His daughter Violet, who was very close to him, gave me a very different picture of her formidable father. He was a man of intense feelings, great sensitiveness, and wide interests; he loved poetry, biography, and fiction, which he read in his dressing gown for two hours every night before going to sleep. But he detested feeling when irrelevant as bad taste. He had the standards of a Stoic and an iron self-control. It was not without reason that he was called the last of the Romans.

The third figure in my trio, John Buchan, was junior to the others, a pupil of Murray's and a friend not so much of Asquith as of his brilliant son Raymond, who like so many others of that remarkable but doomed generation, never returned from the war. John Buchan was also a classical scholar of distinction, who, when he read modern poetry, philosophy, and history, did so with Sophocles, Plato, and Thucydides approving or murmuring over his shoulder. He was in a sense a Jack-of-all-trades, as he has made clear in his autobiography, *A Pilgrim's Way;* he was in turn a publisher, a mountain climber, a South African administrator, a historian (he wrote a twelve-volume history of the first war), a novelist (he wrote some twenty-five successful novels), a biographer of Augustus and Cromwell, a member of Parliament, and a governor-general of Canada. Here certainly was a man whose contact with the world was made on a wide perimeter. But through all these activities there was an interior unity, a firm core of standards, which showed themselves clearly enough when he dealt with the shapeless fiction and impenetrable poetry that have been so fashionable in recent decades. Of these standards, he wrote, "one was a belief in what the French call *ordonnance,* the supreme importance of an ordered discipline both in matter and style. Another was a certain austerity—I disliked writing which was luscious and overripe. A third was a distrust of extreme facility; a work of art, I thought should be carved in marble, not in soapstone." It is reassuring that so discerning a critic should have written:

> You have to go to America, I think, for the wholly civilized man who has not lost his natural vigour or agreeable idiosyncrasies, but who sees life in its true proportions and has a fine balance of mind and spirit. . . . They are a people in whom education has not stunted any natural growth or fostered any abnormality. They are Greek in their justness of outlook, but Northern in their gusto. . . . As examples I would cite, among friends who are dead, the names of Robert Bacon, Walter Page, Newton Baker, and Dwight Morrow. [*Pilgrim's Way,* p. 271.]

If you know these names and prefer them to the three I have taken, I shall be content. They were all hewn from the same rock.

Here, then, are some samples of what I have sketched as the ideal university product. All were men of catholic interests. All were habitually reflective and notable for their judgment—intellectual, aesthetic, and practical. All had a touch of Stoicism in the firmness with which they had themselves emotionally in hand. All held administrative posts in which they proved that they could act as well as dream. This, I suggest, is the type of man that a university should aim at producing. He is an intellectual without being a prig, a scholar undrowned in his own erudition, an academic who is, or can be, a man of the world, a mind that has not only contemplated in its ivory tower the subtleties of the philosophers and the visions of artists and poets, but has allowed itself to be permeated down to the last fibers of its being by that love of reasonableness which is the most precious distillation of any study. A nation whose pattern of life was set by men of this stamp would be the model and envy of the world.

The Central Question

Is our culture producing such persons? Certainly it has an impressive machinery for doing so. No students ever had access with the same freedom as ours to the world's store of knowledge. The belief in education is almost a religion for Americans, and as John Buchan says, the education they believe in is a rounded one; they have the Greek ideal of the healthy mind in a healthy body. A larger proportion of the people, for all their numbers, are in institutions of higher learning than is true anywhere else. It has never been so easy for ability to find subsidy, and our graduate schools are models for the world. And it is surely undeniable that our universities are in fact turning out men of light and leading. What broader-gauge diplomats could be asked for than George F. Kennan, John J. McCloy, and Frank Graham? What more variously cultivated journalist could be found anywhere than Walter Lippmann? What more level-headed public servants could be asked for than the Rhodes scholars who serve as secretary of state and chairman of the Senate Committee on Foreign Relations, and fill two chairs of the Supreme Court? We need not worry about affairs committed to such hands as these.

Granted this, it remains true that we are producing fewer such men than we ought. Since we do in fact produce a small crop, year by year, of these humane and well-equipped minds, there can be nothing in our educational system that necessarily blights them. Yet it pro-

duces so limited a crop of them, and with such effort and expense, as to suggest something inhospitable in the American soil. What is this? There is no simple answer. A swarm of moles and beetles of many different species has been gnawing away at our cultural roots, both inside and outside the universities. I will try to ferret out a few of them.

APATHY

First is the fact that intellectual distinction receives so little honor in this country. I am not thinking about monetary reward, though much could be said about that, too. I am thinking of spontaneous interest, respect, and admiration for work of the first quality in the humanities, for example. In his farewell address as commissioner of education a month ago, Dr. Sterling M. McMurrin declared that the nation's culture was "pervaded by the decline in respect for the intellectual quality of men." For two years recently I have sat on a committee of the American Council of Learned Societies charged with the pleasant task of selecting nominees for ten splendid awards of $10,000 each. They were to go to the ablest humanistic scholars in the country in recognition of distinguished work completed or in process. Our committee spent much time, pains, and discussion in winnowing out a group of scholars in literature, history, religion, philosophy, and art, who, if they had lived in Germany, would have received the honor paid there to the most eminent of its professors, and if they had lived in France or Britain, would have been elected to the French or British Academy. The selections were made with the advice of leaders in the scholar's own field, so that the choice would be as near as possible to an accolade from massive authority. It seemed to me that this crowning of ten leaders of American thought should be on page one of newspapers and magazines throughout the country, that it was almost as important as the choice of a bathing beauty queen at Atlantic City or the escape of a convict from Alcatraz. In fact, the news struck the public with the detonation of a dropped pin. The *New York Times*, committed to presenting "all the news that's fit to print," did include an item about it somewhere in the middle of its Sunday edition, but even Argus-eyed *Time* did not deign to notice it, and the hungry cameras of *Life* found nothing of interest in these intellectual faces. Now mind is not so hardy a weed that it will grow anywhere at all. It needs not only a soil of opportunity but also an atmosphere of encouragement and a little of the sunshine of heartfelt honor. We provide the soil with unexampled generosity. But we are niggardly of air and sun.

DISPROPORTION OF RETURN

Second, there is very little relation between quality of work and the quantity of economic return for it. Perhaps I may illustrate again from my own limited experience. In war days I had a telephone call from Washington saying that an attempt was being made to enable men in army camps to go on with their own education and that the army needed a philosophy book which would further this laudable purpose. The book was wanted in about three months, and four philosophy teachers were being asked to collaborate on it; would I serve? I did. Of course it was done hastily, and I am afraid superficially in off-hours, but it went into paperback and was picked up after the war as a textbook. I found that a casual left-handed product of this kind was far more profitable than books that cost six to fifteen years of work; indeed, if the three of this latter kind that I have laboriously produced were put together, they would leave me well in the red. The moral is clear. If economic return is important to you, don't put quality first; give that place to textbooks or to immediate popular appeal.

If you do not do this, you may well be a gentleman, defined as a man without visible means of support, but you will hardly be what is called a success. On the other hand, if you do catch the ears of the many, your success may be fabulous, for America is the richest of all markets; one best-seller may bring wealth. But quality and success remain two different things. The head of the University of Missouri School of Journalism has reported that in terms of sales the most successful author in American history was Mrs. E. D. E. N. Southworth. Augustine Birrell remarked that "*Charley's Aunt* has made more money than would be represented by the entire fortunes of Sir Walter Scott, Thackeray and Dickens all added together." Sometimes a scholar has the courage to use the success of a second-rate work as a springboard into work of higher quality, as Will Durant did with his *Story of Philosophy*. But that is not the general pattern. For persons who can do both kinds of work there is a continuing temptation, and sometimes a relentless economic pressure, to do the kind that taps the widest range of purses, the more irresistible because the reward of success may be so overwhelming. In short, economics lines up with popular interest to back the second- or third-rate mind rather than the first, and to make the first run under wraps.

OVERDIFFERENTIATION OF THE SEXES

Third, there is the curious fact of the overdifferentiation of the sexes in this country. At first glance the fact seems quite the opposite. Education at all levels means increasingly coeducation; politically and legally, men and women are equal; women are now doctors, lawyers,

ministers, and powers in business; indeed, they own the larger part of the country's wealth. True, but what of the images of the two sexes in the public mind? Here history has played a trick on us, aided and abetted in recent times by the glossy magazines and Hollywood. They have conspired to make American women too sweetly feminine and American men too toughly masculine. Youth, romance, and the bloom of beauty have been so played up that the woman who has moved beyond them, however much a person, is apt to feel forlorn, and the spectacle of Russian women working in the fields and almost monopolizing the medical profession strikes the American as somehow unnatural. On the other hand, as H. G. Wells pointed out, the ideal American man is a square-jawed, two-fisted fellow, cool in crises, ungiven to words, but much given to deeds that spring straight from a heart of gold. This ideal is a heritage of the frontier; indeed, it is inherited from much farther back; all men in a sense are Walter Mittys, compensating in dreams of this kind for the drabness of the gray flannel suit and the unglamorous daily round. One reason why Hollywood has been so preoccupied with the frontier is that it gives this side of us a rich and swashbuckling release.

Now this extreme differentiation of men and women has had an unhappy cultural effect. It has tarnished the gentle lives of the scholar, the thinker, the poet, and the artist with a suspicion of unmanliness. These are not, as a rule, of the two-fisted type, and to that type there is something a little effete and decadent about them. The three men I have mentioned as the finest sort of university product were all of them sturdy physically, but they were not of the square-jawed type, nor were they much interested in competitive sports; their interests, even in youth, ran to literature, philosophy, and politics; they loved poetry, and read the classics with enthusiasm, and distinguished themselves for devotion to exact scholarship. One cannot help wondering whether a boy with these interests in a Jonesville high school or college would not be regarded as a long-haired "square" and a "queerie." So far as I know, such interests are untouched by any stigma of effeminacy in France or England, perhaps because the tradition still lingers there of an aristocracy that respected them, whereas our aristocracy has been of another kind, in which force and business drive have been more prized. For a boy interested in the humanities, our frontier tradition is still something of a hurdle. He finds a further hurdle in his own ignorance. He probably does not know that boys develop more slowly than girls on the linguistic and appreciative sides, and that he is not really as unpromising here as he seems. Too often and too early he is pushed by these impalpable forces away from humanistic studies into others that seem more masculine and more prac-

tical—engineering, medicine, economics, science, business administration. I do not complain about the strengthening of these useful professions. I do deplore the resultant watering down of that precious cultural component, the quality of mind and spirit, which is contributed by education to public life.

THE PRESSURE TOWARD UNIFORMITY

Fourth, there are all the powerful pressures toward uniformity in American life and education. These are the penalty of our size. When individuals move in masses, their edges get rubbed off, like those of the pebbles on a beach, and the larger the mass, the smoother they are and the less important they seem to themselves and others; in overpopulated places like India and southern Italy, one can feel the dispiritedness in the air. The same holds in education. In a class of five, the student is, or may be, an active participant; in a class of five hundred, he relapses into a note-taker. Now the class of five is hardly practicable in America, for when millions must be educated, mass methods are inevitable. Our vast educational machines tend, therefore, to grind out graduates as like each other as their diplomas. And the pressures toward uniformity still surround them when they have left the college gates. Little by little local journals of opinion and discussion are being mowed down by such weeklies as Henry Luce's with their incomparable coverage, photography, and power of suggestion; everything the American hears on radio or television is interlarded with psychologically skilful touts which, in the case of cigarettes, for example, seem able to drown out the voice of the medical profession. We seem to be verifying Emerson's remark that "society everywhere is in conspiracy against the manhood of every one of its members." We have been called a land of status-seekers surrounded by hidden persuaders.

With all this din in our ears it is hard to think or to have an inner life that is genuinely our own. But think we must if thought is to go on at all. Crowds cannot think, nor journals nor radios nor even universities. Only individuals can think, and only as the habit of such thinking is encouraged and kept alive has education really succeeded. No doubt that is why William James broke out in a letter to a friend:

> I am against bigness and greatness in all their forms, and with the invisible molecular moral forces that work from individual to individual, stealing in through the crannies of the world like so many soft rootlets, or like the capillary oozing of water, and yet rending the hardest monuments of man's pride, if you give them time. The bigger the unit you deal with, the hollower, the more brutal, the more mendacious is the life displayed.

So I am against all big organizations as such, national ones first and foremost. . . . Give me individuals. . . . [Ralph B. Perry, *The Thought and Character of William James*, II, 315.]

The three men I have taken as exemplars were all intensely individual. You could not mistake any of them for any other, in spite of their common interest in truth and reasonableness. Their voices were not echoes; their thought and feeling had the freshness of authenticity. One of them, Asquith, made a weary entry in his journal about some of his colleagues: "They can only think talking, just as some people can only think writing. Only the salt of the earth can think inside, and the bulk of mankind cannot think at all." This power to think inside is threatened in America by forces that are peculiarly insidious and universal. Professor Walter Raleigh, when on a visit to this country, wrote a letter home with a remark that sticks like a burr in my memory: "There are no persons here." The remark was rhetorical, unjust, and untrue. But even as one's gorge rises, one sees what he meant.

THE COMPLEXITY OF MODERN LIFE

Among the enemy miners and sappers we must note, fifth, some of the material conditions of modern living. It is hard to maintain in the midst of them that citadel of quiet reflectiveness which should be there as our strength and our refuge. The three men I have named were born in the Victorian era, when domestic life was largely based on personal service. There were maids to make beds and get meals; there were handymen whose wages one could afford. The vacations of these men, as college students, were not filled with hard physical work, necessary to earn one's way through. The kind of mind I have sketched may be achieved in the unhurried freedom of the English squire; but his class has hardly existed in America; and even in England increasing taxes imposed from above and increasing wages required from below have all but destroyed it; men—and still more, women—must do for themselves what used to be done for them.

It may be answered that a world of gadgets has taken the place of human service and that the work day is growing shorter. But the gadgets have now so multiplied that they have become themselves a care. The speeding car, the buzzing telephone, the complicated toys for Junior, the coughing and expiring power mower and the anxious do-it-yourself kit, the weary commuting to work of our increasingly urban people, the mountains of mendicant mail, the recurrent struggle with income tax, the protracted niggling necessary to finance a college education for all one's brood, regardless of their powers, the shoals of newspapers and magazines that call for attention if one is to keep abreast of the times—in a word, the sheer complexity of modern life,

seems to make the ideal of serene thoughtfulness a rainbow in the clouds. The very perfection of those techniques that pile the news of the world on our doorsteps, almost at the hour of its happening, is more calculated to enlarge our information than to give us a philosophy, a standard of value, or a habit of reflection. And information without these is not education at all.

THE NEW DEMANDS OF SCIENCE

I must mention, though hesitantly, a sixth and final danger to our liberal education. In recent years and for obvious reasons the claims of science in education have been forced upon our notice, and indeed forced down our throats. There is no doubt that we need more science. If Sir Charles Snow and the secretary of defense say that we need it for national safety, I accept what they say, though I should add that we need it anyhow; the scientific way of thinking is part of the equipment of any educated mind. But if anyone says that a scientific education by itself is a liberal education, and just as liberal as one in the humanities, I beg leave to differ. My reason is that science, for the most part, ignores persons and their values, and persons and their values are the most important things in the world, indeed, the only things that are intrinsically important. Mathematics is concerned chiefly with classes as such, and whether they are classes of poets, popes, or pebbles is irrelevant. You could read many volumes of physics and chemistry without running across a suggestion that there is such a thing as consciousness in the world. Since consciousness is not public and observable, as good scientific objects are supposed to be, even psychology deals with it in a slightly shamefaced way. But consciousness, with its loves and hates, its idealism and despair, its visions and its villainies, is the sole residence in the universe of good and evil.

In view of the pressure put upon us for more and more science, it is well to know where we stand, and perhaps I may be permitted to say with dogmatic brevity where I stand myself. First, from a utilitarian point of view, science is essential. Second, it affords an admirable intellectual discipline. Third, that discipline is no better than an equally rigorous discipline in history or philosophy; indeed, I incline to regard these latter as better, for the reason that they engage our prejudice, and straight thinking in them is therefore an exercise not only in logic but in objectivity, in intellectual ethics, in the detection and control of wishful thinking. Fourth, even if this advantage is an illusion, it will be conceded that art and literature provide food for imagination and feeling which a scientific diet can hardly supply. And for the estimation of the goods and evils of life, imagination is of more use than

logic. Finally, if world opinion were consulted at this moment, I suspect that we should be told quite bluntly that what we most need, as a people, is not so much more science as more of that humane wisdom required to use aright the tools that science has piled around us. I am not belittling science, which would be a stupid thing to do. I am saying that the educated mind must have qualities of sympathy and taste which science is not well calculated to supply, and that the substitution of a scientific for a humanistic core in liberal education would for us be a mistake.

These considerations may be felt to be "airy nothings." Granted that the test of a university is the sort of person it produces, granted that this person is of the kind I have sketched, granted all these difficulties in the way of producing him, is not the real question what we should do about it? What do you propose, I may be asked, about a new production belt for turning such persons out in satisfactory numbers? On that very different question I propose to say nothing. Not that I take no interest in educational engineering and in getting public support for it. These things are immensely important. No one could think the mechanics of education unimportant who worked, as I did for many years, under that remarkable Swarthmore pioneer, Frank Aydelotte, who did so much with his system of honors seminars to break the educational lockstep and set the abler students free to move at their own pace; and I would commend to your attention not only that experiment but all the other devices canvassed in Dr. John Gardner's recent book on *Excellence*. I am much in favor of state aid to education and think we have ground for protest against the way in which a statesmanlike bill for such aid has been blocked by sectarian interests. We need more junior colleges; our teachers need more money; our teaching methods, particularly in the languages and the sciences, need revision. These things are important, I repeat. But they belong among the means of education, not its ends, and one of the chief American temptations, here as elsewhere, is to confuse ends with means. A mammoth high school, a crowded campus, a football team with all wins and no losses, an expensive faculty, a B.A., a Ph.D.—these are not ends in themselves; they are tags and devices that take such value as they have from the persons they label or help to produce.

Some persons are in a position to forward American education by munificent gifts, and this splendid institution would have been impossible without them. Most of us cannot aid in this way. But there is one way in which all Americans can aid who have been through a university's doors. They can justify their alma mater by valuing what it values, and by trying to be the sons and daughters it deserves. The most convincing witness to the value of education is a living, breath-

ing human being whose habitual speech and action are invested by distinction of mind.

In giving that witness, we in America have to resist the inverted snobbery that makes the educated man feel uneasy if he is not like everyone else. He is too often afraid that if he uses the language more sensitively than other people, if he interests himself in Eliot's criticism or Barth's theology, if he tries to embody his own taste in his dress or the layout of his house, he will be accused of being "high hat." Now education has surely failed if it leaves us like everyone else. Our graduates should not simply dissolve and disappear in the democratic melting pot; they ought to lead in every community, not as a result of their own pushing, but as a result of gravitation to the top by minds and characters that plainly belong there. Of the three men I have mentioned as university types, I am particularly drawn to the politician among them, Asquith, because on this point he never compromised. In his political campaigns he may have kissed babies and milked cows (though I doubt it), but he always argued with the knowledge and urbanity, thought with the relevance, and spoke with the distinction of the gentleman and scholar. I remember feeling the same admiration for Woodrow Wilson when, as a middle western youngster I heard him make a campaign speech; here was no man's copy, but a mind speaking to plain men and most persuasively in the unmistakable accents of the scholar. "The rule for every man," Wilson once said, "is not to depend on the education which other men prepare for him, —not even to consent to it; but to strive to see things as they are, and to be himself as he is. Defeat lies in self-surrender."

So it does. Surrender to the mass mind is one of our chief dangers. That we should bear our individual witness is all the more important because, as education becomes more widespread, the dead weight of numbers may pull it down; its attractve power may no longer be sufficient to pull them up. No expenditure and no legislation will ever give it this power. Only one thing will. That is the potent magnetism of living examples scattered about the land, minds of light and sweep, persons that we can admire and envy and seek to emulate. What James Russell Lowell said to Harvard at its two hundred and fiftieth anniversary may safely be repeated to Rice at its fiftieth: the ideal of the college should be "a man of culture, a man of intellectual resources, a man of public spirit, a man of refinement, with that good taste which is the conscience of the mind, and that conscience which is the good taste of the soul." Whether or not it produces such men is the test of a university.

MAURICE EWING

Sediments of Ocean Basins

THE STUDY of the history and evolution of the earth by examination of deep-sea sediments might be likened to the study of the history and evolution of man by the diggings of archeologists.

In both cases we have to establish a time scale. In both we expect to find the older layers beneath the younger. In order to draw conclusions about climate and environment from either continental or oceanic deposits, we must remain alert to possible misinterpretations resulting from elimination, contamination, or reworking of parts of the sediment, and we are greatly interested in the geographical setting and the detailed topographic relationships of the material studied.

But the scale of operations is quite different in the two cases. Archeologists consider time in thousands or hundreds of thousands of years; and areas covering only a few acres. To draw meaningful inferences from the ocean sediments, we must consider time in millions, or even billions, of years; and areas covering as much as half of the earth's surface.

As man and beast have left in the soil and rock the history of their development, physical characteristics, environment, and way of life, so the planet earth has left in the oceans the least distorted account of the major events in its evolution.

What kinds of events can be read in the deep-sea sedimentary deposits? As a rough rule we may say that, to be recorded in the deep-sea sediments, a change must be world-wide in scope and must last for at least a thousand years. The activities of mankind have contributed very little material for this record, for until the present time man has done but little that modifies his environment on a world-wide scale.

It is easier to mark a layer of sediment by the addition of foreign matter as a tracer than to modify the bulk composition of that layer.

MAURICE EWING is Higgins Professor of Geology and director of the Lamont Geological Observatory of Columbia University. This lecture was presented in the Grand Hall, Rice Memorial Center, at 2:00 P.M., October 11, 1962.

For example, we often dredge up clinkers dropped from the boilers of steamships. The clinkers are sprinkled sparingly, but extend over wide stretches of ocean and are made of resistant and quite distinctive material. Buried at a rate of about 1 millimeter per 1,000 years, this modest record of man's accomplishment may be preserved and accessible to a skilful investigator after other widespread evidence has eroded away.

Another evidence of our way of life which may leave permanent clues on our planet is alteration of the CO_2 concentration in the atmosphere and ocean water. There is as yet no positive demonstration that the CO_2 returned to the atmosphere and ocean from burning coal and oil after millions of years of burial has had any major effect. But ultimately the effect of burning fossil fuels might be enough to have a minor, but world-wide, permanent, and measurable effect on the chemistry of sea water and air. Some think that the change in atmosphere may eventually modify our climate.

Modification of isotope ratios by nuclear reactions may ultimately make in the deep-sea sediments an even clearer record of man's activity.

Looking to the future, these are some of the ways in which we may leave our record. Looking into the past million years, we find that earlier climates are in some cases clearly revealed in the ocean sediments. The glacial and interglacial periods of the Pleistocene epoch are well recorded in the faunal changes in the calcareous sediments. These are sediments which consist largely of the remains of organisms which concentrate calcium carbonate. World-wide climate changes altered ocean surface temperatures enough to favor some species of Foraminifera during glacial periods and others during interglacials. The calcareous remains in different strata show us whether cold-water or warm-water species predominated when that layer was deposited.

Some of us hope to find a record of much earlier times, believing that the rough surface of the solid basement rocks beneath the deep-sea sediments may be billions of years old and, in fact, may be the original surface of the planet before alteration by rains, oceans, rivers, and cosmic debris. If so, it will contain clear evidence of the conditions which prevailed before the atmosphere and the ocean protected the earth from bombardment by meteorites. There is a remote possibility that the surface of the basement beneath the ocean sediments is pocked with craters like those of the moon.

Other scientists believe that the slate was wiped clean, by one means or another, one to two hundred million years ago, and that no record of earlier times has been preserved on the sea floor.

We are on the verge of being able to settle these questions. Grid

surveys using the new continuous seismic-reflection technique will permit us for the first time to "look" through the sediments and map in detail the basement contours to see what can be inferred from their three-dimensional topography.

Continental Drift and Convection Currents

What could have "wiped the slate clean" and changed the earth's original surface? There are several possibilities. For example, there has been long-standing support of the idea of continental drift in a way which would make the floors of the Atlantic and Indian oceans much

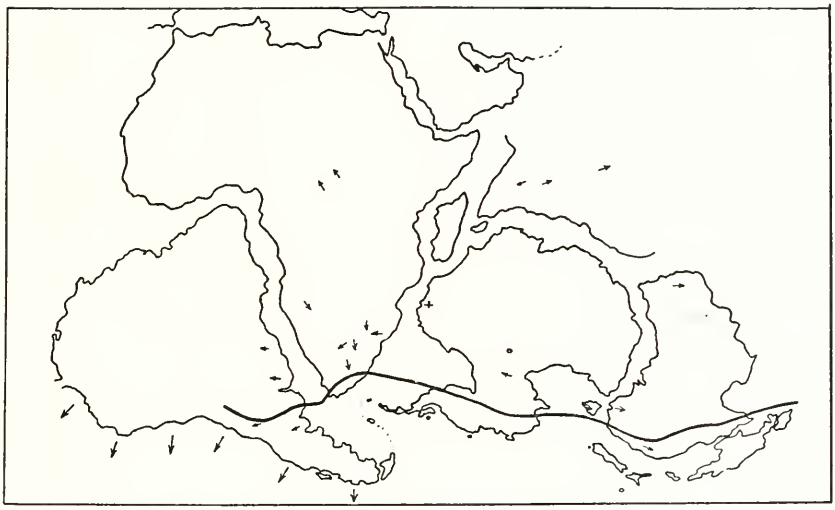

Fig. 1.—Assumed ur-continent of Gondwana Land

younger than the neighboring continents. According to this idea, the continents of the southern hemisphere originally formed a single continent. That continent broke up into pieces that moved apart during the time between Cretaceous and Jurassic (from 80 to 150 million years ago). This motion supposedly created the Atlantic, Indian, and Southern ocean basins, as shown in Figure 1. Similar action has been postulated for the continents of North America and Europe. The most conspicuous evidence supporting this view is the nice "fit" of the American and European-African continents, if slid over and joined. Various ideas have been advanced about occurrences in the Pacific during the time of continental drift.

It seems almost certain that the creation of vast areas of new ocean floor and destruction or disturbance of old ocean floor implied by

such hypotheses could not have occurred without leaving clear evidence for the student of sediment distribution.

It has recently been suggested that convection currents in the mantle shift the continents about, with the outpouring of new crust occurring under the mid-ocean ridges. Now it has been further suggested that these currents extend outward across the floor of the ocean and sweep the sediment and crust under the continents (Fig. 2). This hypothesis for explaining the thinness of the Pacific sedimentary

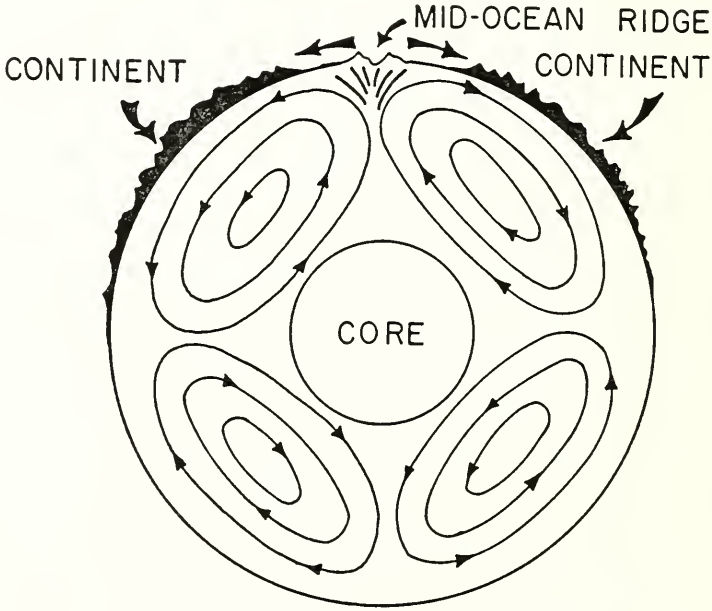

Fig. 2.—Convection cells in the earth's mantle

cover is, incidentally, much more difficult to support in the southern (or ocean) hemisphere than in the northern. In the southern hemisphere, continents are too small and too far apart to provide many subcontinental hiding places into which ocean-wide deposits of sediment could have been swept.

Our surveys, still very incomplete, have as yet revealed no hiding places for sediments in the oceans.

There is strong evidence in support of each of these divergent viewpoints—continental drift with disposal of pre-Cretaceous sediments on one hand and stability with a long-continued collection of sediments on the other. At the present time, new evidence is arriving at a great rate, and each bit of it must be weighed against two hypotheses. Does the observed mass of sediment represent the accumula-

tion of billions of years and open to us the possibility of reading in the sediments almost the whole of earth history? Or are they the sediments of only a few hundred million years, representing only the last chapter of a long earth history?

If such fundamental discoveries may be made by examination of the ocean sediments, why have earth scientists not got the answers?

The Sediments

For many years now geologists have fully realized that the sediments, if properly known and understood, ought to yield the history of the earth. In 1899 the British scientist W. J. Sollas tried to estimate the duration of geologic time by adding together the greatest thicknesses of the strata representing each period of geologic time and dividing this total by the present rate of sedimentation. It was an ingenious idea, but of course it is not possible to fix an "average" rate of sedimentation. Even the present "rate of accumulation" can be little more than a guess. The results of such guesses have been interesting, but necessarily meaningless as long as our real knowledge of the sedimentary processes and rates is so fragmentary.

Until now our knowledge of the sediments has come mainly from several techniques: dredging, which skimmed to only a few centimeters within the sediment; coring, which penetrates up to ten or twenty meters; rock dredging, in which we try to break off rocks exposed on steep cliffs; echo sounders, which in some areas show stratification in the sediments to depths as great as forty meters below the sea floor; and extensive use of ocean-bottom photography, in which we confirm the existence of large areas of bare rock.

Finally, there are the seismic-refraction methods, which give us some information about the degree of consolidation of the sediments and the rocks on which they rest, as well as the layer thickness. Refraction measurements, until now, have been our principal source of knowledge about the total volume of deep-sea sediments. Though far better than none, they are a poor source, because from them we can obtain, not the thickness at a chosen point, but only the average thickness over a line twenty to fifty miles in length.

Before the refraction measurements were introduced about twenty-five years ago, we had only estimates or guesses of the amount of deep-sea sediment, and the range of estimates was wide. Very low values were given by those who viewed the continents as the source of sediments, then tried to calculate the maximum loss which the continents could have sustained, and imagined this material spread over the much larger area of the ocean floors. On the other hand, impossibly large estimates were obtained by those who measured or esti-

mated a rate of deposition and (assuming that the present conditions are representative of the past) multiplied that rate by the billions of years during which the earth has been in existence.

The questions raised—about the age of the earth, the nature of its original crust, the total thickness of sediments and their distribution, continental drift, convection currents—all these exciting questions will not for much longer be so-called academic questions. Within the last two years enormous strides have been made both in our ability to sample the entire column of sediment and our ability to map the world-wide sediment distribution and pinpoint the places where it will be most important to drill deep columns of sediment.

Seismic-Reflection Method

In January, 1961, a method for measuring the total thickness of the sediment layers on the floor of the deep sea and observing its stratification was developed under the direction of John Ewing. All my subsequent studies on this subject have been made in collaboration with him.

Recognizing the importance of this measurement, we have added it to the list of our standard underway measurements which include water temperature and depth, gravitational and magnetic field strength. We have also chosen the tracks of Columbia University research expeditions to favor the study of sediment distribution.

The measurements of sediment thicknesses are made by means of sound waves. A small bomb (from 1½ to 2 lbs.), usually exploded just beneath the sea's surface, produces the sound. Part of the sound is reflected back from the sea floor, and part of it penetrates into the bottom and is then reflected back from stratifications in the sediment and from the rock floor on which the sediment rests.

The separation of the echoes indicates the thickness of layers. The measurement is repeated at intervals of two or three minutes along the entire track, while the ship is underway at speeds of up to ten knots. This ability to work at normal ship's speed is of great importance, for it makes it possible to obtain continuous world-wide lines of data without cutting into costly ship's time available for other important programs. In general, there is no doubt about the continuity of reflecting horizons mapped over distances of hundreds of miles.

Sediment thickness has now been measured along about 150,000 miles of track—mostly in the Atlantic. The thickness ranges from nothing up to a few kilometers (except along some continental margins, where it is greater).

The pattern of sediment thickness has provided many surprises and promises many more. The greatest surprise has been the thinness of

the sedimentary layer. If sediments have been deposited at a steady rate (even as slowly as 2 cm/1,000 years) over a geologic time, they would be piled many, many times thicker than we find them to be. Either the time of accumulation is far shorter than the age of the oceans, or the mean rate is far less than the present one.

To understand the meaning of what we have learned in the last two years about the thickness and distribution of sediments, it is necessary to be familiar with the principal kinds of oceanic sediments and with the sedimentary and structural provinces which characterize the Atlantic and Indian oceans. I will digress now and state those necessary facts as quickly as possible.

Oceanic Sediments

Calcareous sediments, as mentioned before, consist largely of the remains of organisms which concentrate calcium carbonate. These sediments dominate in water depths less than 2,500 fathoms (2½ miles). At depths greater than that, sea water is more corrosive and would dissolve the carbonates. Great expanses of the oceans lie at depths less than 2,500 fathoms. These include the broad mid-ocean ridges of the Atlantic and Indian oceans, which form between one-third and one-half of the area in these oceans. The accepted rate of accumulation for the carbonate sediments is 1–4 cm/1,000 years, based on a few radiocarbon dates. We need additional dating here. It is the sampling rather than the actual radiocarbon assay which is open to question.

Red clay (or lutite) is the other important deep-water sediment type. It is deposited in water depths greater than about 2,500 fathoms, that is, in the basins between mid-ocean ridges and continents. It is considered to be the residue remaining after the corrosive deep waters have dissolved the carbonates. The accepted rate of accumulation is about 1 mm/1,000 years (the thickness of a dime in 1,000 years). There are still difficulties in the radiochemical and faunal dating of red-clay deposits. There is also great need for sampling red clay under the guidance of the new results on sediment distribution. Perhaps it can be shown that the accepted rates for both types are much too high for the present era and that present rates are much too high to be representative of the past.

By *terrigenous* sediments we mean those which have come rather directly from the continents (1) by slumping down the steep continental slopes, or (2) by the turbidity-current process which has sorted out sands and silts and spread them over the modern abyssal plains, or (3) by some process which only now is being recognized as able to take the fine, clay-size particles of continental debris out

many hundreds of miles to sea and deposit them in such a way that they fill the depressions to form and maintain a smooth, almost level surface at all stages of accumulation, even on a rough rock floor. The greatest deposits, in area and thickness, which we find in the oceans appear to have originated in this way.

Our use of the term "terrigenous" is more restricted than the conventional one. We use it to describe particles which have moved from the continents, generally downslope and along or near the sea floor.

Pelagic sediments include all sediment which has originated from materials that were held in the sea water and widely distributed by its motion. Pelagic sediments cover nearly three-quarters of the ocean bottom and include the calcareous sediments and the red clay just mentioned. Other pelagic sediments are (1) siliceous ooze, composed of the remains of either diatoms or Radiolaria; (2) small particles of continental debris which by action of winds or currents have become very widely disseminated; (3) the finer components of volcanic ash; (4) extraterrestrial matter, whose total contribution cannot yet be accurately estimated; and (5) deposits from direct chemical precipitation from the sea water, the contribution of which is also almost unknown, except in the important case of the carbonates.

Volcanic sediments certainly play a part in our problem, and may originate either from oceanic or continental volcanoes. These sediments have been recognized in many areas. The pumice and lava deposited near to the source form characteristically multilayered deposits. The fine ash is commonly so widely disseminated that it may be considered as part of the pelagic sediment.

These then are the terms in which sediments will be described: *terrigenous*, if the source is basically continents; *pelagic*, if the source is the ocean itself; *calcareous*, from organisms which concentrate calcium carbonate; and *red clay*, below the depth at which the carbonates are dissolved. There are other kinds of oceanic sediments, but these are all that are necessary to understand the principal points in this paper.

Structural Provinces

The structural provinces which characterize the Atlantic are shown in Figure 3. The Indian Ocean is barely sampled, but appears to be similar.

Figure 3 shows the continent (in this case, North America), with a thick, delta-like apron of terrigenous sediments along its margin. From geophysical evidence it is known with virtual certainty that the continents consist of a crustal layer of granite and basalt about 30–45

km. thick, overlain by a veneer of sediments less than 2 km. in thickness.

The ocean basins are typified by a much thinner crustal layer (about 5 km.) with the Mohorovičić discontinuity (the division between crust and mantle) rising to within about 10 km. of sea level. This discontinuity and that between the volcanic and the basaltic crust are known only from seismic measurements.

The continental margins, the borderlands between continents and ocean basins, are complex. They have been difficult provinces to investigate by the seismic methods which have revealed the boundaries between basement, crust, and mantle in both purely continental and

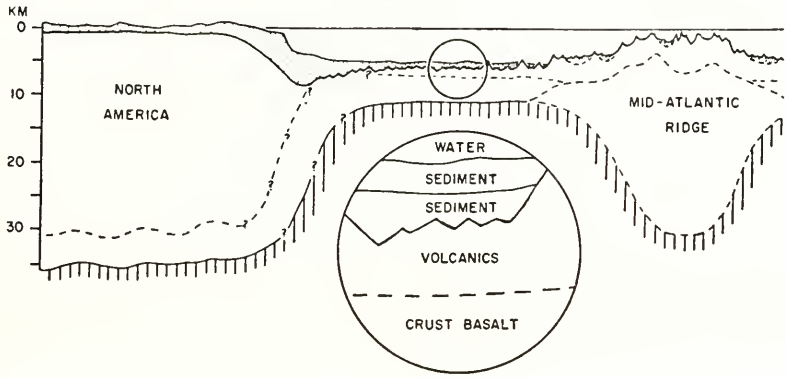

Fig. 3.—Schematic diagram of continental and oceanic crustal structure

purely oceanic provinces. In Figure 3 the structure of the continental margin is shown as questionable because details in the zone where the thick continental crust joins the thin oceanic crust are not yet known.

The mid-oceanic ridge province is shown as a broad, rough rise. The crust under the ridge differs in composition and thickness from that under the basin. The configuration at the border between these two provinces is not known with certainty, but is inferred to be transitional. In all cases the rough rock surface of the ridge appears to be merely a continuation of that beneath the basin.

As shown in Figure 4, the ridge in the Atlantic is a median ridge, remaining approximately equidistant from the bordering continents. This pattern continues through the Indian Ocean and, with alteration of some features, through the southwestern Pacific. There is a narrow, continuous belt of epicenters of shallow-focus earthquakes, which coincides with the crest of the ridge (wherever this is known) along a world-circling belt through the Arctic, Indian, and Pacific

oceans. This epicenter belt marks the locus of the principal belt of present tectonic activity in the ocean basins.

There are a number of ridges, tributary to the mid-oceanic ridge system, which do not exhibit seismicity. Their relation to the active belt is not yet clearly established.

NORTH AND SOUTH ATLANTIC SEDIMENTS

Let us now examine some results of sediment measurements across continental margins. The chart (Fig. 4) shows the locations of some lines of profile off North America, Panama, the Pacific coast of South America, Palmer Land, and Africa. These are samples which represent types of continental margin found in various areas.

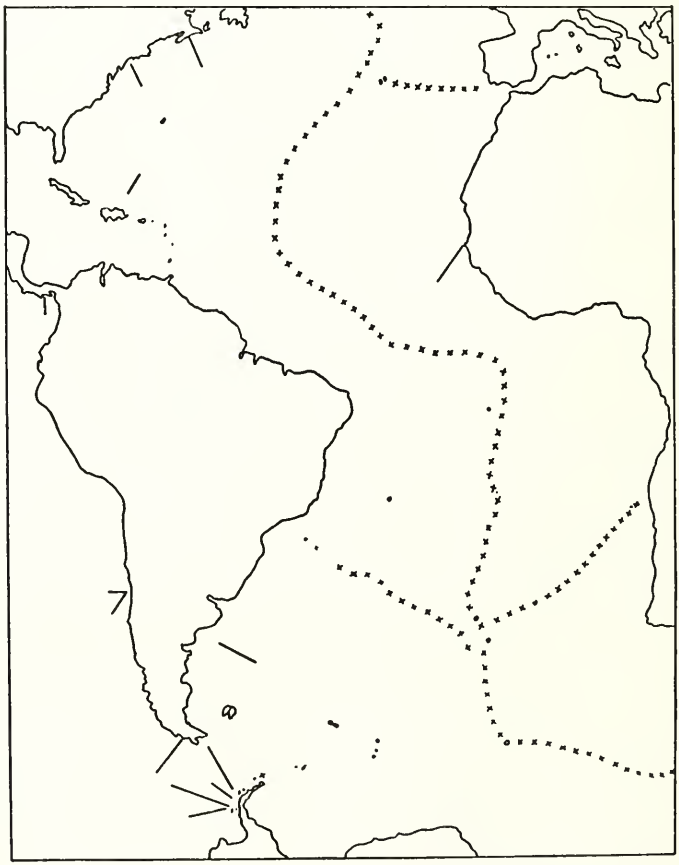

Fig. 4.—Sketch map of Mid-Atlantic Ridge. Lines show the profile locations for Figs. 5 and 9.

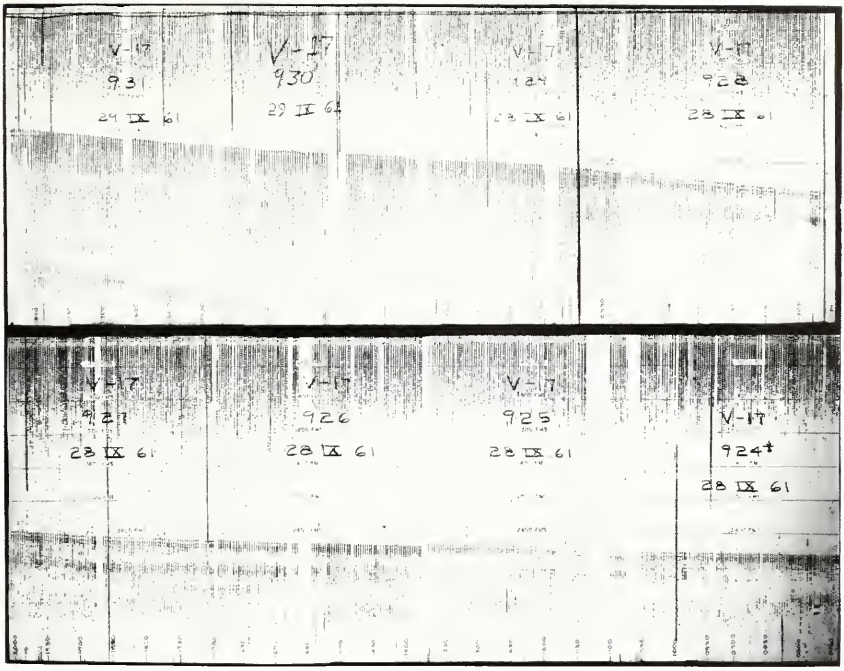

PLATE I.—Profiler records across continental rise off New York

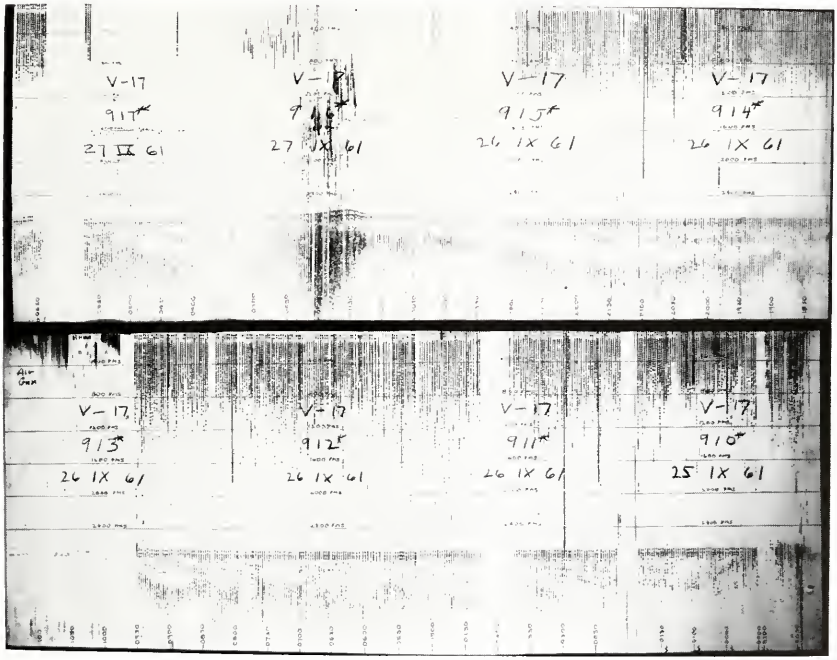

PLATE II.—Profiler records in basin south of Halifax

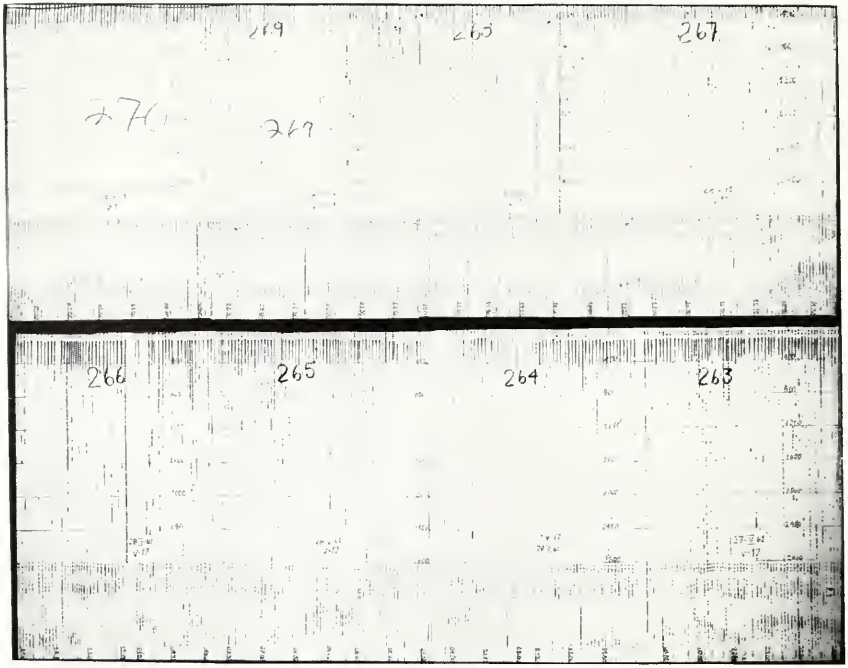

PLATE III.—Profiler records in Argentine Basin. Sheet numbers correspond to locations shown in Fig. 7.

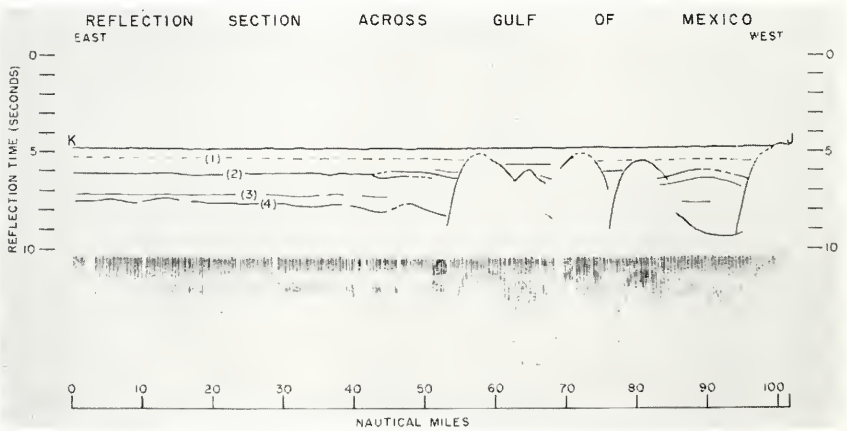

PLATE IV.—Profiler record across Sigsbee Deep and Sigsbee Knolls

Figure 5 shows some of these sections, with reflection time in seconds, or roughly, depth in kilometers. They all show strongly the effect of the continents which they border, that is, many reflectors, each of which is almost parallel to its neighbors. These layered reflectors dip toward the sea in a way that suggests that this kind of continental margin is like a very large delta.

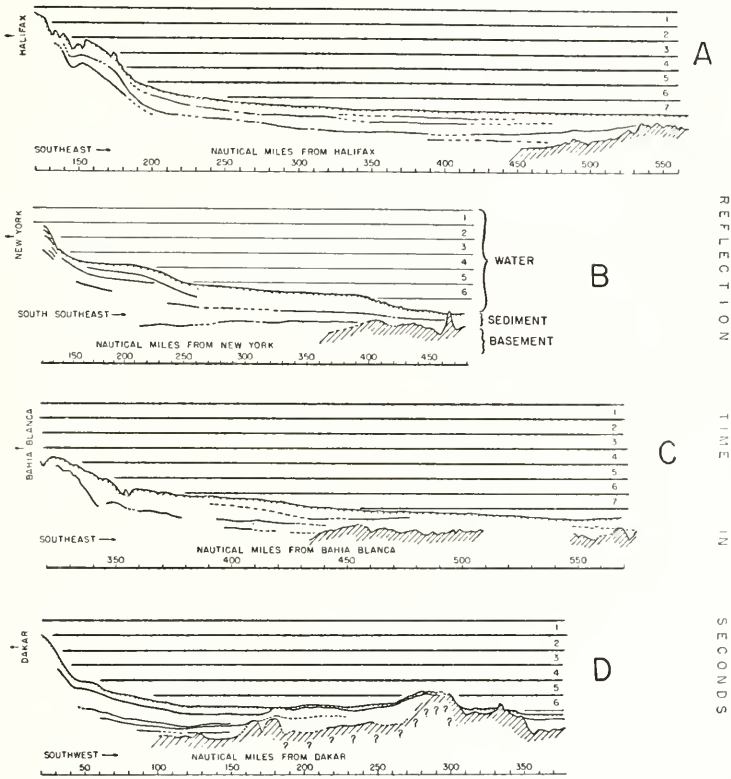

Fig. 5.—Tracings of profiler traverses—Halifax, New York, Bahía Blanca, and Dakar. Locations given in Fig. 4.

Farther offshore some of the sediments show characteristic basin structure; that is, a smooth ocean floor and an even smoother interface (horizon *A*), overlying a rough basement which produces a strong reflection. Basement is indicated by crosshatching. The sediments above and below the smooth interface must be relatively unconsolidated because we receive a strong reflection from the rough basement floor on which they rest. Consolidated sediments would not permit the sound waves to penetrate well enough to return such a strong reflection from underlying basement.

These sections have many features in common and may be considered as typical for the Atlantic.

Plate I shows the original reflection record across the continental rise between New York and Bermuda. The two halves of the record ought to be considered as fitting from end to end and representing a distance of about 250 miles. Full vertical scale is about 10 km.

At the landward end of this section (top left) there is a multiplicity of almost parallel reflecting layers—typical "continental effect." All of the coherent traces seen on these records represent real reflecting surfaces, except the deepest one on the landward end, which is a multiple of the reflection of the ocean bottom.

At the seaward or basin end of this traverse (bottom right) the pattern has changed gradually to become typical of ocean basins, that is, smooth ocean floor, an even smoother intermediate reflector, and

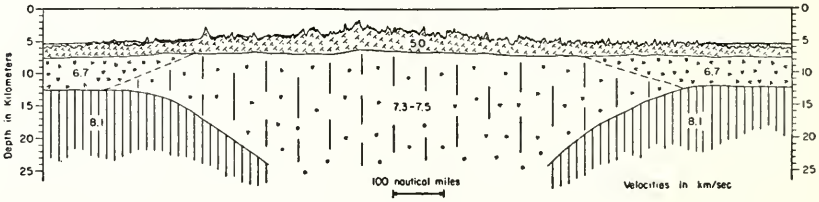

Fig. 6.—Section of Mid-Atlantic Ridge from seismic measurements

strongly reflecting rough basement. The basement apparently dips toward the continent and is not detected under the landward half of the traverse.

Plate II shows some of the original reflection records taken along a line south of Halifax, Nova Scotia, and ending about 200 miles from the start of the segment shown in Plate I. This illustrates several important points. Throughout most of its length it displays typical basin structure, particularly the smooth interface, horizon *A*, and the rough, strongly reflecting basement surface. Two noteworthy features are the small hill in the ocean floor sediments on sheet 916* and the multiple stratification in the sediments in sheet 910*, at the lower right corner of the plate. These stratifications are attributed to volcanic sediments from the nearby seamounts of the Kelvin Group.

Figure 6 shows the structure of the Mid-Atlantic Ridge determined from seismic-refraction measurements. The numbers in the various strata indicate sound velocity in km/sec. The rough topography of the ocean floor and the thickness of the sediment are copied from the seismic profiler record of a traverse from Dakar to Halifax, crossing the crest of the ridge in about 30° N. lat.

It is evident that the sediments are extremely sparse on the ridge and that they have collected in pockets. This mode of accumulation is characteristic of traverses in the North Atlantic; but in the South Atlantic the ridge sediments are draped over the rough topography as a layer of uniform thickness. In both areas the mean sediment thickness on the ridge is about the same, 100 to 200 meters. The fact that the ridge sediments in some areas are in uniformly thick layers draped over the rough basement topography and in others are flat-topped pockets filling basement depressions is attributed to the local slopes being too gentle in the former case to initiate turbidity current transport.

The sediments in the basin have the characteristics mentioned earlier and illustrated in the inset circle in Figure 3. In the majority of traverses the sediments of the basin continue from the continental margin entirely to the ridge, reaching it at a depth less than that which is critical for carbonate solution.

But in some cases the basin sediments gradually become thinner toward the ridge and terminate before reaching it, leaving between basin and ridge a deep, rough area which has been called abyssal hills. The abyssal-hills province has only a very thin cover of red-clay sediment, though it is deeper than either of the adjacent provinces, in both of which the sediment thickness is considerably greater. We consider that the abyssal-hills province is beyond the range of encroachment of the terrigenous sediments on one side, and below the depth of carbonate solution on the other.

The body of sediments in the North American Basin (between the mainland and the ridge, with Bermuda at about its center) is the major deposit so far discovered (or likely to be discovered) in the North Atlantic. An even larger one has been found, and rather thoroughly surveyed, in the Argentine Basin. A chart showing some of the profiler traverses of the Argentine Basin is given in Figure 7. The basin sediments here show precisely the same characteristics mentioned before, as illustrated in reproductions of the original records in Plate III. (Locations indicated in Fig. 7.)

The similarity of structure of the continental margin for these two major sedimentary basins is shown by the two profiler sections *AA′* and *BB′* in Figure 8. (Locations given in Fig. 7.)

The additional stratification shown under the continental rise in *AA′* is attributed to superior operation of the equipment, rather than to a real structural difference.

It is surprising that the total sediment volume in the Argentine Basin is greater than that found elsewhere, particularly since we have

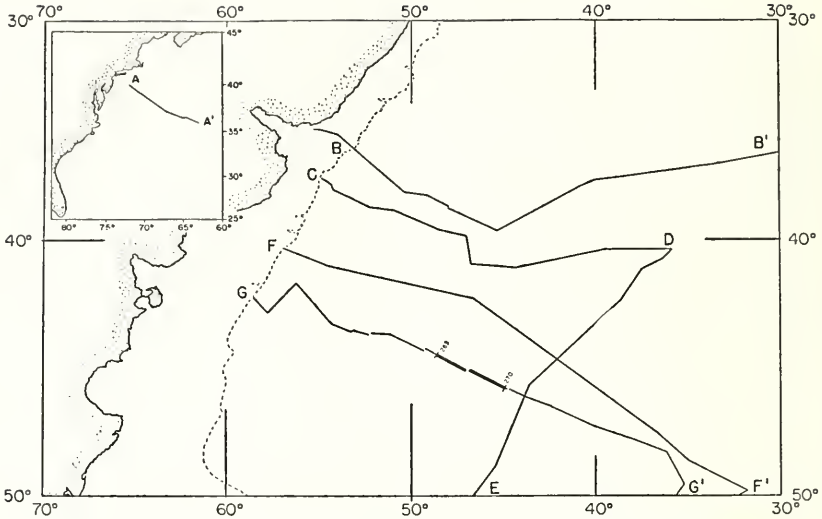

Fig. 7.—Tracks for profiler measurements across the Argentine Basin

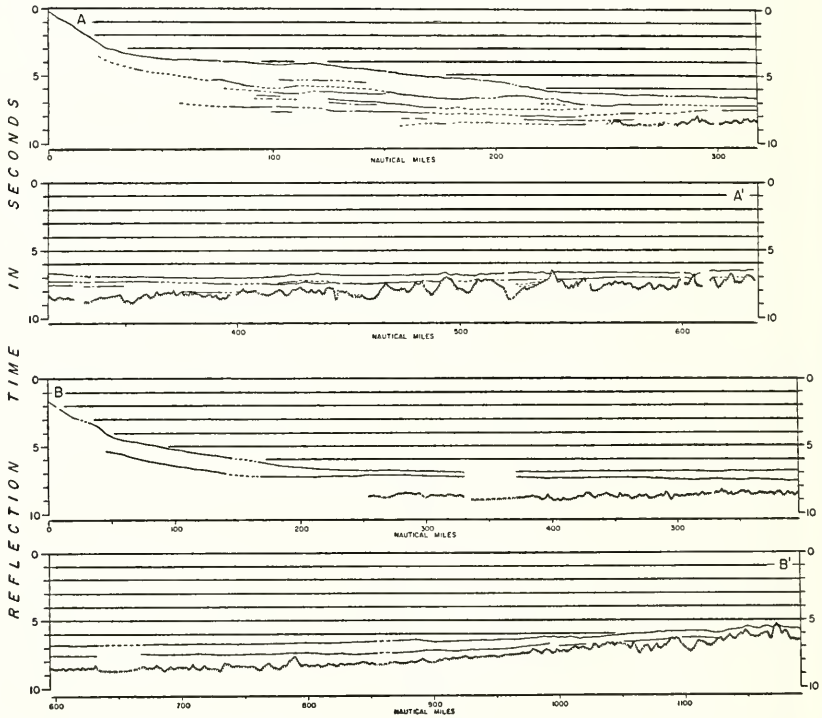

Fig. 8.—Profiler traverse across continental margin and into the basic sediments: off North and South America into the Atlantic.

evidence that the basin sediments are terrigenous and since the area of continent near this basin is so small. This can best be explained by differences in "sediment productivity" in different continental areas.

It should be noted that only relatively small bodies of basin sediments have been found outside the Atlantic, that each of them found so far is adjacent to a continent, and that in every one of them there is a unique reflector, apparently correlating with horizon *A* of the Atlantic. This horizon evidently records a unique event in the sedimentary history of the oceans.

PACIFIC MARGINS

Figure 9 shows by contrast the sections off Panama and South America into the Pacific. No great delta-like pile of sediment is seen here. Some process is forming a trench here, forming it fast enough that the sediments do not overflow it; and the most sediment in any of these sections is near the smallest amount of continent—namely, off Tierra del Fuego. The locations of these sections are shown in Figure 4.

These sections contrast in all important respects with those for the Atlantic. The contrast is great—perhaps as great as might be expected if, through continental drift, the shores of the Pacific are moving together while those of the Atlantic are separating. But are the differences right in detail to support these supposed differences in history? We have not sampled enough different continental margins to make positive claims that these sections are typical for all coasts of the Pacific.

But, on the assumption that these few samples are typical, we may note an absence of indicators that the continent has been plowing through, or overriding, or is being undercut by the oceanic crust and any body of supposed sediments.

These sections rather give the impression that a very small total amount of sediment has been delivered from the continent, that there is at the foot of the continental slope a trench whose floor has progressively tilted toward the continent, that the sediment was deposited by turbidity currents to provide a level floor, and that the sediments have a strong "continental influence" which provides several reflecting horizons and evidence of progressive tilting.

This entire situation is consistent with the idea that (*a*) the total sediment delivered to ocean basins from continents is very small, (*b*) throughout much of geologic time there has been a "sediment trap" along the Pacific coasts of the Americas which caught the sediments that now form the western mountain ranges, and (*c*) that the modern

trench along South and Central America is trapping sediments in a way that probably represents the beginning of the next cycle of the mountain-building process.

GULF OF MEXICO

The multiple stratification which has been described above as evidence of "continentality" of a sediment body is well displayed in the deep basin of the Gulf of Mexico. Seismic studies here have led

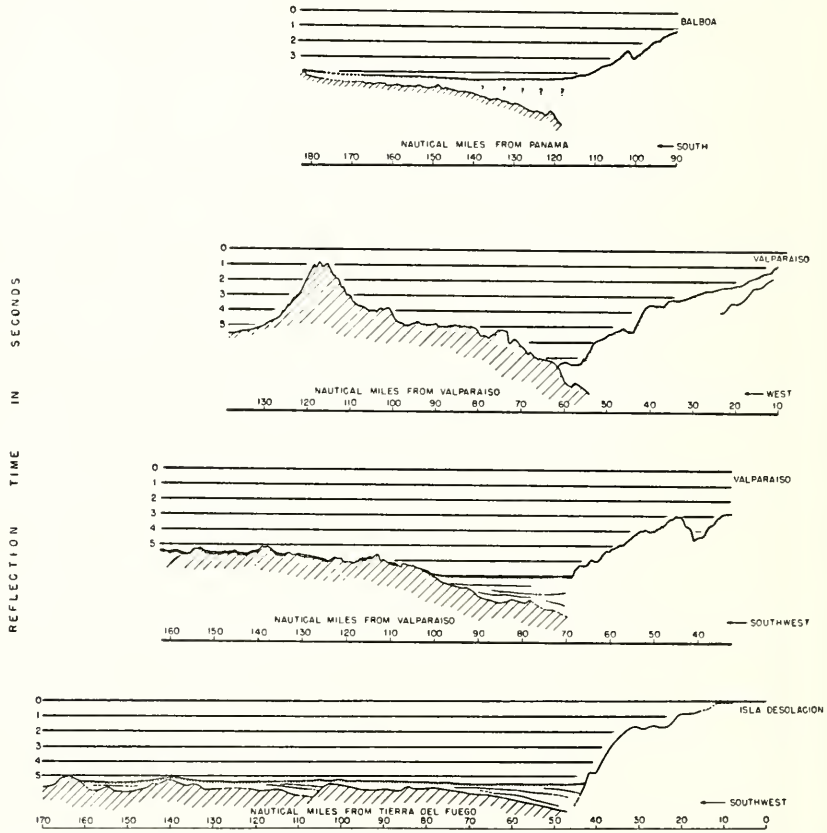

FIG. 9.—Profiler traverses from Panama and South America into the Pacific. Locations given in Fig. 4.

to the conclusion that the earth's crust beneath is typical oceanic crust, depressed by an enormous pile of flat-lying sediments more than 5 km. thick. We have suggested that these sediments have accumulated to such a thickness because spreading was prevented by the boundaries of the Gulf. The conditions found in this sediment body

may be unrelated to the world oceans, but they have a particular relevance to the world of Texans.

An early profiler survey was made in the deep basin of the Gulf of Mexico (1). It showed marked continentality in the sediments, that is, a thick column of numerous, nearly horizontal beds. When combined with earlier seismic-refraction measurements, these data led to the conclusion that the floor of the Gulf of Mexico was originally oceanic crust, which had been depressed somewhat by the weight of a great

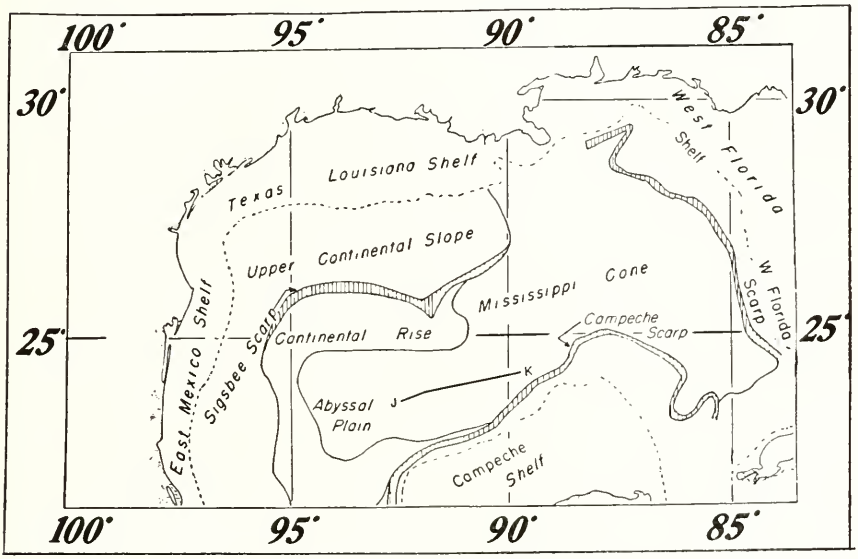

Fig. 10.—Gulf of Mexico: Physiographic provinces and location of profiler traverse (*J–K*).

pile of sediments to a depth too great to be followed by the profiler reflections.

A feature of particular interest was the discovery of numerous diapir or dome structures in a zone trending east-northeast along the axis of the deep basin (Fig. 10). The cores of the domes are composed of nonmagnetic material, and the question of whether they are salt or some other low-density sediment has many interesting implications.

Some of these domes are completely buried beneath the Sigsbee Abyssal Plain (Pl. IV), while others rise a few hundred meters above the plain, constituting the Sigsbee Knolls, discovered in 1953. For those which show only a few meters of topographic relief, the rate of growth has been estimated to be on the order of 1 mm. per year (2).

Thus we see that the sediments on the floor of the Gulf exhibit other evidence of continentality—diapirs or salt domes similar to those of the Gulf Coast.

Conclusions

There are many apparent contradictions in the 150,000 miles of sediment data we have now examined. The unexpected paucity of the sediment cover is perhaps the most striking feature. The complications in accounting for the lack of sediments are compounded by the still more puzzling pattern of their distribution, that is, the fact that thickness of sediment does not seem to bear as simple a relationship as anticipated to distance from a continental source.

Each bit of evidence on sediment distribution which we find must be interpreted on the basis of at least four different basic assumptions.

1. *Permanence of continents and ocean basins,* that is, the sediments at every place represent the accumulation of billions of years.
2. *Continental drift, continents moving through mantle material,* implying that the central parts of the Atlantic and related oceans have been accumulating sediments longer than the marginal parts.
3. *Continental drift, continents being carried along by convection motion of the mantle,* implying that the central part of the Atlantic crust is younger than the marginal parts. (Continental drift of either type is usually attributed, on paleontologic evidence, to the Jurassic-Cretaceous interval.)
4. *Burial of all pre-Cretaceous sediments by extensive lava flows.*

In examining each new sediment profile, we try to determine which of these views is supported by the evidence in it. The answer has not yet emerged, but with enough data, it will.

In conclusion it might be noted that, in an era in which drilling into the deep-sea floor is being planned, the profiler studies have defined many new targets for exploration by the drill—targets whose very existence was not previously known. A rapid, flexible method for selecting drilling sites is provided, one which at present can give information beyond our powers to interpret it. But the situation will improve rapidly when more surveys are made or when samples from the first core holes become available.

At this Semicentennial celebration, it is tempting to compare conditions in 1912 with those at the present. When Rice was newly begun, the collection and analysis of deep-sea sediment was in its infancy. Most of the existing data was from the *Challenger* expedition. No cores had been taken, seismic prospecting methods had not been introduced, and, as far as I can judge, oceanic drilling would have seemed a fantastic dream.

As the dream of William Marsh Rice has become a reality and Rice has come to be acknowledged as one of the world's great universities, so the realization of our dream to read the earth's history by means of the ocean sediments is not far in the future.

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Note: Contribution from the Lamont Geological Observatory of Columbia University Number 632.

SAKAE YAGI

Problems of Engineering Education in Japan

It is a great honor and pleasure for me to be invited to this Semicentennial ceremony of your renowned William Marsh Rice University and to be given this opportunity to speak to such a distinguished audience.

As you know, my country, Japan, has a population of nearly 100 million living within an area slightly larger than one-half the state of Texas, which naturally makes her heavily dependent on the development of industry. Therefore, the education of engineers is of extreme importance to Japan, a fact which I believe is of interest to you also, especially as engineering has undergone many changes and developments during the last half-century.

This is the subject on which I wish to speak today, by first discussing the philosophy of engineering education in universities, followed by its historical background in Japan, and ending with the various problems of Japanese engineering education.

Philosophy of Engineering Education in Universities

Education is most influential in determining the future of the individual student, of the specialized field, of the nation, and of the society. Of course, many educators are practicing what they consider to be the best methods, without fully realizing the immensity of their responsibilities.

Education increases the number of people useful to society. The primary objective which educators must always keep in mind is to provide students with a background so that they can make full use of

SAKAE YAGI is chairman of the Department of Chemical Engineering of the University of Tokyo and president of the Japanese Society of Chemical Engineers, Japan. This lecture was presented in the Physics Amphitheater at 2:00 P.M., October 11, 1962.

their human abilities for the happiness of the individual and the happiness of human beings as a whole. The problem is how the above objective can be achieved in contemporary society.

Educators cannot ignore the historical background of the country, the district, or the particular institution in question. Even in a time of revolutionary change, education still retains some of the influences of the past. On the other hand, it is also true that theories concerning education and its methods are constantly being examined and changed. This is important. The influence of the past together with this constant necessity for change brings about contradictory effects, but we must keep in mind that the real characteristics of education exist within this contradiction.

Therefore, when we discuss the problem of engineering education, it is wise to view it with a perspective covering a quarter or half a century.

Now we shall take engineering education in universities as one example. It should provide the fundamentals for the ways of thinking and the judgment to be used by an engineer during his long career. Engineering itself advances day by day, and there seems to be little meaning in simply teaching engineering as it presently exists. Moreover, as engineering has become very complicated, it is impossible to teach it in complete detail. Therefore, the main purpose of engineering education in universities should consist in providing the basic potentiality which can be employed for engineering and its development.

Engineering education in former days was begun with the purpose of educating technologists who could enter practice readily, instead of providing engineers with potentialities for future growth. It was regarded as the most important objective to educate these technologists for industries. Such education has really contributed very much to the development of civilization, and above all to technological advancement. This is the type of education we have in many universities at present and will continue to have in the future. But it is evident that engineering education cannot regard the preparation of technologists of this type as its sole objective, when we stop to consider the remarkably rapid progress of technological civilization. Engineering education today must be the type of education which prepares one for the distant as well as immediate future.

Engineering education in universities today is carried out by many staff members and with the co-operation and influence of many different specialists and departments of universities. Therefore, it is difficult to generalize upon the philosophy of engineering education. I believe, however, that it should be based on the tripod of "training,"

"systematization of the science," and "research activity," similar to other specialized fields.

It is my firm belief that if one leg of the tripod is shorter than the others, the value of the education for engineers is very much reduced. In practice, however, engineering education in each university acquires its own distinctive characteristics by putting greater weight on one leg of the tripod according to the areas of concentration it selects and the nature of the institution.

In engineering education especially, it is desirable that research results be assimilated into practical technology rather quickly. However, the research activity in universities is accompanied by the other two requirements—training and systematization of the science—which are lacking in the research activity of industrial circles and government bodies. As a result, there are some significant differences among the research activities of different organizations, and this tripod concept above constitutes the special characteristic of university research. It presents, at times, a valuable *raison d'être* for researchers in universities.

Let us now discuss the systematization of science. The systematization of science in engineering involves two phases: one is the integrated educational system, namely, the curriculum, and the other is the systematization of each science. The curriculum is firmly related to the individual sciences and is formed by taking into account the education in each specialized field and its future potentiality. The curriculum, therefore, should be so prepared that the education will bring about lasting growth of students and the staff members, not merely achieve the fulfilling of the needs and requirements of the present. Thus, the formation of the curriculum is an important responsibility of educators.

The systematization of each individual science should be the prime motive of research activity in the university; and the educators who belong to fields involved in technological development must especially recognize fully this important responsibility. Such educators co-operate with the industrialists for the development and progress of technology with a common objective, though from different standpoints. By different standpoints I mean that it is desirable for educators to complete the system of the science which they themselves created as educators.

The modern tendency of science shows that as science develops it becomes more specialized. But from the standpoint of education, it is necessary to assimilate science so that it becomes more suitable for teaching, for example, through scientific simplification or abstraction. This is sometimes very difficult, but it can be considered as an impor-

tant home task for those who are engaged in engineering education.

The next problem is that of the relationship between engineering and pure science. This can also be considered as a problem of the curriculum and of the system of engineering science. Engineering is supposed to be very firmly related to pure science, and both should have very much in common, but the former regards technological objectives as very important, while the latter makes the pursuit of truth its prime objective. Both have recently become highly developed and specialized, and it is said by some that the gap between engineering and pure science is becoming wider.

I think we can point to the inflexibility of educational institutions as being one of the causes of the gap. Therefore, both the curriculum and the systematization of engineering should be constantly examined and improved. Engineering education should be continuously related to all basic sciences, and, if possible, it should have many common phases with other specialized fields. Ideally, they should all be unified in a simple form. It is a very difficult issue in the case of a highly developed engineering education, but this point must be taken into consideration in the education of creative engineers.

The ideal type of engineering education should, therefore, be in the form of abstracted and organized science rather than in the study of many technological problems. It should have as its objective not only the pursuit of truth as in the case of pure science, but also usefulness or the possibility of usefulness through the application of research. This type of research cannot be achieved by individuals, but only by many groups of people and through the accumulation of their research efforts. At the same time, each engineering researcher, or each of those who engages in engineering education, should have a scientific philosophy of his own.

I have discussed above the importance of the tripod of engineering education, namely "training," "systematization of the science," and "research activity." Now I think the balancing of the above three factors is even more important. When only the training is stressed, the trainee may become a good technician, but he may be restricted in his ability or may lack imaginative power. When the systematization of science is regarded as too important, there may be produced a theorist who lacks practical ability and cannot think realistically. When only research activity is practiced, there is a danger of producing only a narrow specialist who lacks the possibility of future development as a creative researcher. I firmly believe that a properly set-up tripod correctly indicates the future course of the university or the engineering and specialized fields.

The next problem in engineering education is that of economics. It

goes without saying that engineering is based on the rules of economics, and, at the same time, engineering creates the opportunity for significant economic situations, which can be illustrated by many historical examples. According to one theory, an ideal engineering teacher may be compared to a millionaire. All goes well if this is the case. However, the ultimate objective of educators is often reached only after a quarter of a century, and we may have to be resigned to the fact that our successors rather than we might be the millionaires.

Historical Background of Engineering Education in Japan

Engineering education in Japan, like her other higher forms of education, was begun as one link in the chain of national reconstruction efforts activated by the Meiji Restoration of 1867, which had freed the nation from Shogunate control and its closed-door policy against the world. This education was centered at certain institutions which subsequently became part of the multicollege Tokyo University. For instance, technological education was first begun in 1873 at the six departments of engineering in the Engineering College (Kobu Daigakko) and also in 1875 at the Department of Science in the School of Occidental Studies (Kaisei Gakko). They seem to have attained university level about the time when the Tokyo University was reorganized as the Imperial University in 1886.

The new Engineering College within this Imperial University, which had been formed by combining one segment of the Department of Science and the bulk of the former Engineering College, had seven departments, consisting of civil, mechanical, electrical, mining and metallurgical, and naval architectural engineering, plus applied chemistry and architecture. This was about the time in the United States when independent departments for mechanical engineering and electrical engineering were first established.

This Engineering College had two complementary parts, a theoretical one for research activities and a practical one for direct technical guidance, in which respect it was the sole institution of higher learning for creating leaders for the engineering world.

Industry at the time was either state-operated or run by public organizations, but with the turn of the century, the growth of national power and the rise of private enterprises necessitated the establishment of four new imperial universities and sixteen national technical colleges in various parts of the country. The five imperial universities handled the education of researchers and engineering leaders, while the sixteen national technical colleges trained engineers or high-class

technicians, and the two together contributed greatly toward raising the industrial level of Japan.

The imperial universities followed the example of the first one in Tokyo, while the national technical colleges concentrated on practical training to produce technologists who could be immediately useful in industries. From this time, universities and technical colleges began to increase until in 1945, at the time when World War II ended, there were 3,000 graduates per year from the engineering departments of ten universities and about 13,000 graduates a year from the sixty-five technical colleges in existence.

Of the above two groups of institutions, most of the universities were state-operated and had the name of Imperial University. I shall now briefly explain the main characteristics of the University of Tokyo where I am teaching, which has served as the pattern for many of the universities in Japan.

Since its establishment in 1877 as Tokyo University, its name has been changed to Imperial University (1886), then to Tokyo Imperial University (1897), and finally to the present form, University of Tokyo (1949). It took as its model the European type of university; in other words, it was fashioned after the *studia generalia* or *universitas*. It had a strong tendency toward giving priority to research and left education itself to the initiative of the students. As a matter of fact, those students who could attend this university were the proud select few who, burning with a passion for learning, had passed through the quasi-privileged Higher School (state-operated junior college), which was extremely difficult to enter.

I remember a famous professor when I was a student at this university more than thirty years ago, who used to say jokingly, "Don't take too much care of Tokyo University students. The more you leave them alone, the better they will become."

Traditionally, its School of Engineering placed a strong emphasis on the basic sciences, for which many experts had to be brought in from the School of Science, while the younger members of the staff had no chance of getting a chair unless they had previously creditably led a class in the basic sciences. Actually, the common classroom and laboratories in this school for mathematics, applied mathematics, dynamics, physics, and applied physics had been developed by the School of Engineering as a whole, while its various courses in basic chemistry had been promoted through the co-operation of the Department of Applied Chemistry and the Department of Chemistry in the School of Science.

Although the terminus of university education was the graduate thesis, the various specialized lectures which introduced studies on the

applied sciences and the findings of the professors were often considered valuable preparatory material. The tendency spread to other imperial universities until it became the accepted method of education at university level. This group of imperial universities was the brain center of the nation for a long time, supplying research data and experts to governmental and other research institutions as well as technical leaders to the industries. It could be called the pivotal center of Japan's industrial development.

The graduates of the technical colleges, although their term of education was two years shorter, had the advantage of intensive practical training which enabled them to tackle difficult problems immediately upon joining the industries. This fact, combined with their numerical strength, accounts for their substantial contribution to the advancement of Japanese industry.

When the war ended, this double structure of engineering manpower was abolished by a strong "recommendation" of the occupation forces, which enforced a standardization of education according to the American 6-3-3-4 system. As a result, the former universities had to shorten their regular courses by one year, but the new graduate-school system was established. The former technical colleges began to combine with other colleges and were raised to university status. This caused a tremendous increase in the number of universities. In 1960 there were as many as 250 universities, of which 72 were national, 33 public, and 145 private. As for the engineering or technical departments in these universities, there was a total of 67 schools of engineering with 20,500 graduates for the year, consisting of 11,500 from the national, 800 from the public, and 8,000 from the private universities. Furthermore, the shortage of engineers in recent years has caused a continued remarkable increase, particularly in private universities. It is said that the total number of engineering graduates numbers about 40,000 a year at present.

Problems of Engineering Education in Japan

Thus, the engineering educational system in Japan, which was practically completed about fifty years ago, had to make drastic changes after the war which naturally created many difficult problems. These can be attributed to two sources: namely, changes in the concept of university education and actual confusion caused by the rearrangement of the education system. Along these lines, I wish to discuss the most important problems which are confronting us.

The Japanese university, as explained above, used to enroll only a small number of entrants screened for sufficient ability and preparation for higher learning. It used to be a place which provided a suit-

able atmosphere to make the students grow with their own efforts in company with the professors and the staff. But the postwar education system, which is based on the principle of equal opportunity and advancement through training, provided a standardized education for everybody.

This has caused great consternation and confusion among the university people who had been accustomed to the old ways. However, it cannot be denied that this change was necessary for the new Japan, which had lost one-half of its prewar land and resources, as well as for the development of modern Japanese technology. It was in one sense a birth of a new nation and a reconstruction like the Meiji Restoration of 1867.

In facing the new age, we should not discard what is good in the old, nor should we hesitate to adopt what is good in the new. However, since education is a complicated activity requiring the efforts of a large number of people, it is impossible to obtain perfection immediately. It requires a long period of time, great perseverance, and an untiring pursuit of the ideal.

Engineering education in universities received the full impact of the new educational system and the new concept of university education. One of the effects was a qualitative change in the young people seeking to enter the universities. The new system seems to give greater emphasis to social and human consciousness than formerly, but, on the other hand, even considering that this is a transition period, it creates rather less enthusiasm for technical and scientific study.

The second point is that at the former imperial universities the students had three full years of specialized education, whereas this has now been virtually reduced to two years, causing complaints of general deterioration in specialized knowledge. This was due to the inability to discard the traditional ways. At the same time, the former technical colleges, which have suddenly risen to university status, tend to follow the ways of the imperial universities and seem to have lost much of the emphasis on rigid practical training which used to be their tradition. Therefore, it seems that the good points of both types of schools have been lost.

These problems have been actively discussed by the Japan Society for Engineering Education, composed of people from universities and the industries, on the basis of a report by Harold L. Hazen and others in 1953, published by the American Advisory Mission for Engineering Education, and other reports of the American Society for Engineering Education. However, education problems are never easy to solve. Probably there is no way except to spend much time and effort to find one's own solution. At present, the chief problems that

have been taken up concern budget increases for the graduate-school system, methods of maintaining the education level in newly established universities, and those problems related to educational efficiency and the full development of the new graduate schools in older universities.

Before going into the important problems connected with engineering education, allow me to say a few words concerning my personal history.

After graduating from Tokyo University's Department of Applied Chemistry in 1928, I worked for several years in a chemical company, when I began to question the shape of engineering education and then took part in establishing the chemical engineering laboratory at the Tokyo Institute of Technology, which had recently become a university. In 1937–39 I had an opportunity to study the educational methods of chemical engineering and chemical technology in the United States and Europe.

I often harked back to the former School of Engineering and the Department of Applied Chemistry, which formed the historical background of Japanese engineering, and found myself wondering what course chemical engineering education should take in the future. In 1936 I took part in establishing the Society of Chemical Engineers of Japan and also in 1940 in establishing the Department of Chemical Engineering at the Tokyo Institute of Technology, the first of its kind in Japan. I was later given the responsibility of establishing the Department of Chemical Engineering at my alma mater, the University of Tokyo, which is the most influential university in Japan.

Since then, I have been engaged in the study and academic systematization of what is considered the weakest spot in the Japanese engineering curriculum, namely, the combination of chemistry with chemical engineering, known today as chemical reaction engineering.

Here, let me return to the question of engineering education in universities. As previously explained, it is a study of a balance among the three factors—training, research, and systematization of science, which are the three legs of the tripod—and of what should be done with them.

Among these, I believe that systematization of science should form the center of university education. This includes the preparation of the curriculum and an academic systematization of the specialized courses taught by each professor. Since the latter is the very life of the professor, I feel that all research and training in universities should be advanced along this direction. I dare say that it would be a loss for university education if the university or the staff should select research subjects incompatible with the development of the science sim-

ply because of shortage in research funds. If the subject becomes the flesh and blood of the professor by being sublimated and simplified through intensive research and students' training, it would naturally permeate most effectively and efficiently into the students. But to decide whether this principle serves as a useful foundation or means for engineering education at present and for the future rests with the responsibility of the university professors and of the academic society of which they are a part.

Many problems remain in the technical phases of engineering education. But modern engineering education, aside from a few exceptions, becomes more effective by being better organized and by becoming more closely related to the basic sciences. Enginering sciences, too, are interesting examples. Complicated engineering methods which are confined within old shells should be taken out and rearranged. But on the other hand, the wider the range of tools to select from, the better it will be. Simplified principles and wide scientific appeal would greatly stimulate the creative urge of students, and all research activities along this line would probably give them enough self-confidence.

As one who is engaged in the technological education which is necessary for Japan if it is to maintain its fairly high standard of living, I have given an outline of the course of engineering education in Japan during the last fifty years. I have also touched on the main problems in technological education based on my thirty years of experience.

Education is essentially a relationship between man and man. If the educator's enthusiasm moves the students and brings out their creative talents, one-half of the job can be said to have been successfully accomplished. From there, the professors should continue their efforts with all their strength and perseverance to systematize the studies for which they are responsible, and to endeavor to make their research activities give benefit to their present students as well as to their successors a quarter or half a century from today.

BERTRAND HARRIS BRONSON

"All This for a Song?"

When good Queen Bess, in her large wisdom, ordered Lord Burleigh to give the poet Spenser £100 for his excellent verses, Burleigh is said to have exclaimed in protest, "What! all this for a song?" It can be inferred from the late files of the *Congressional Record* that a similar view is alive today in certain quarters. During last year's debates on the National Defense Education Act, an amendment was introduced in the House, "that no part of the appropriations . . . shall be available for fellowships in the humanities and social sciences field." Earlier, word had reached the press that part of the fellowship funds would be allocated to the study of folklore and "other things like that"; and the bad publicity that followed had so alarmed the committee that already they had cut the funds by a million dollars before bringing up the bill for debate. Congress was mollified by this evidence of discretion; but anxiety was not entirely dispelled.

> I know of no reason [declared the mover of the amendment] why under the National Defense Education Act there should be studies of . . . English folklore, and American folklore. What is the difference between English and American folklore? I will be pleased to have any member of the committee tell me the difference and why we should be providing fellowships under the National Defense Act to study folklore, jazz, the theater, and so forth. [*Congressional Record*, 87th Cong., 1st Sess., p. 8268. House Debate, May 17, 1961.]

The cash value of *The Faerie Queene* or of *Henry V* would, it may readily be granted, puzzle anyone to establish. As a prudent treasurer, Burleigh saw no need to lay out any of the national wealth in the encouragement of poetry and drama, whatever his private liking for a song or a play. The congressman, in turn, whether or not he got satisfaction from speaking the tongue that Shakespeare spoke, saw the

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matter in the same light, although as a realist he might set a high value on a Broadway success. But, contemporary with Burleigh, there was one who saw things in truer perspective, who wrote with proud eloquence:

> And who in time knowes whither we may vent
> The treasure of our tongue, to what strange shores
> This gaine of our best glorie shall be sent
> T'inrich unknowing nations with our stores? . . .
> What powres it shall bring in, what spirits command,
> What thoughts let out, what humors keep restrain'd:
> What mischiefe it may powrefully withstand,
> And what faire ends may thereby be attain'd?

The odd thing is that neither Burleigh nor the congressman could see these products as national assets, nor was able to imagine any connection they might have with their country's interests at home or abroad. For the practical and utilitarian value to a nation of the theater, jazz, or songs is so much easier to demonstrate than is their absolute value. Indeed, their worth as propaganda is so obvious that folklore in one or more of its manifestations—song, dance, dress, or other handicrafts—is exploited to the utmost by countries behind the Iron Curtain. Certainly, Russian ballet has been one of their most positively ingratiating and valid exports to foreign parts; and it can be argued that Louis Armstrong and Benny Goodman have been two of our most successful ambassadors. Is there any nearer way of allaying suspicion, banishing rancor between peoples, reaffirming the common ties of humanity, and building mutual trust than by sharing popular entertainment together? "No man," Dr. Johnson sagely observed, "is a hypocrite in his pleasures." And when beauty joins pleasure to excite admiration, how much the better! Can we neglect to foster such useful intermediaries of understanding?

Fortunately, the humanities do not have to be vindicated here, in an assembly committed to their recognition, on an occasion so memorably auspicious. If I have raised the issue in a defensive way, it is only because I am concerned with them primarily in one of their humblest walks, and intend to plead that even there they are worthy of serious and prolonged investigation.

Our civilization has become so deeply committed to print for the normal conveyance of its ideas that we tend to ignore the subtler influences of hearsay in our lives. But the latter can be of great importance, and it is the more necessary to be awake to this fact because of their relative obscurity. The persistence of oral tradition in a literate, cosmopolitan, urban society or any segment of it such as the present

company is worth investigation. What sorts of lore—limericks, songs, stories, proverbs, superstitions, games, social conventions—are conveyed habitually in speech from person to person, generation to generation, and at what ages, in what contexts: these form a study richly contributory to a knowledge of our communal living. Even limiting ourselves to songs, we can find matter to occupy us for a long time.

Folk song, to be sure, is a warmly human, natural, and lovable phenomenon, and there can be no complaint against those who wish only to keep it alive and to put it to its natural uses: to dance or to work to it, to express their feelings of joy or love or sadness through it. But because it *is* so spontaneous and universal, it deserves serious attention. There are a hundred ways of approaching it: through social studies of family tradition, or the way of life of its bearers—in the woods, on the plains, on ships, on trains, in the mines; of its regional or geographical dissemination; of its persistence through time as fragmentary history by, and of, the generations; of its disclosure of national character; of its psychological significance in choice of subject matter, character prototypes, themes continually reformulated; of its accepted conventions in the telling of stories; of its deeply rooted preferences in the patterns of melody.

There must be few among you who are not familiar with half a dozen of those British-American ballads of which there are records as far back as the seventeenth century and which may very likely be a good deal older than the earliest records. They are so rooted in our tradition that the same acquaintance could be assumed almost anywhere in the country. Any similar gathering would know "Barbara Allen" from childhood and probably, under varying names, a handful of such songs—perhaps "Lord Thomas and Fair Eleanor," "Lady Isabel and the Elf-Knight," "Lord Lovel," "The Two Sisters," "The Gypsy Davy," or "Lord Randal"—not learned from books but from other singers. If only we could immediately pool all the versions of these known to the present company, we should have in our hands the materials of a very interesting research project. The factors, thus visibly exemplified, of stability and variation, perpetually at odds, would yield fascinating data.

Variation-form in Western composed music has been intensively studied. Yet, although everyone would admit its importance in the ceaseless fluctuation of traditional text and tune, one finds little or no discussion of variation as a phenomenon in folk song. Narrative change has received attention, and verbal change has been noticed incidentally. But musicology in this country is too young a science to have condescended to scrutinize folk song, and melodic change here has gone unanalyzed. Obviously, text and tune are interdependent,

exercising mutual influences. But when we analyze, variational effects, musical and verbal, have to be separately described. The *story* of a ballad identifies itself almost automatically, given a number of exemplars. But we cannot go far in studying a *melodic* theme without beginning to wonder about its identity. What *is* a tune, in fact? Does a series of notes in common time constitute the same tune as a similar series in another meter? Are the tunes of "Dixie" or "Yankee Doodle" the same tunes if sung in the minor as in the major? Yes, we might say, if you allow that one is incorrect. In this case there is an established norm. But what if none exists? Is a tune with phrases repeating, as ABAB, the same with similar phrases in the order ABBA? Can a tune ranging from its lower to upper dominant (or fifth) keep its identity when, with requisite adjustments, it is stated in a form ranging from tonic to upper octave?

A composer, working in variation forms, will put a theme through all sorts of gymnastics. He states his point of departure, and his object is to excite and sustain our interest by ingenious and imaginative transformations of the melodic idea. Since the norm is fixed, he can invent with the utmost freedom, altering one element after another at pleasure. In folk song the situation is very different. True, most of the kinds of variation appear in miniature—as figuration, ornament, changes of cadence, dynamics, mode, pitch, rhythm; suppression of phrase, contraction or expansion; and so on. But these variations have occurred, in the chances of oral tradition, without reference to one another, and mostly without conscious intent—indeed, usually in spite of it. For the traditional folk singer, no archetype exists except the one he learned, the one in his head. There is and can be no true original of a genuine folk song. The beginning is out of sight and, if the original survived, it would be only as another version, unauthoritative and without control over the derivatives that are perpetuating it. What, then, constitutes a folk song's essential identity? Of what is each statement of its tune a variation? Can we say that its identity lies in the sum of persistent resemblances to apparently kindred tunes? That may not carry us far, but, as with the study of other living species of which the prototypes have disappeared, it must force us to comparisons.

Comparisons are not necessarily odious—indeed, they can be fascinating—but they are burdensome, time-consuming, and full of vexation when they are not superficial. Because we have no archetype to start from, we must begin with a miscellaneous gathering of tunes, collected, with whatever diligence, at the mercy of chance; each one differing from every other at least in minute particulars and therefore unique, but having enough in common to strike us as varying forms

of the same melodic idea. What we are pursuing is the precise objective nature of that sensed community.

How shall we start comparing if we do not know that any one characteristic is more symptomatic than any other? If we start with tunes that look alike in their opening notes, we find them wandering apart as they proceed. Or we find more similarity in the *second* phrase of others—or the third—or the fourth—than in the first. Some tunes whose melodic lines are nearly alike may be in quite different meters: 4/4, 6/8, 3/2. Shall we discount on the side of meter or of line? Some tunes have four phrases, some five, some six, some eight. Should this fact be counted essential? The tunes appear in different modes, different scales: how much weight does this deserve in analysis? The difficulty is to set things in order of importance.

In each phrase, the notes that carry metrical emphasis seem more indicative of the melodic line than the notes between stresses. This fact is encouraging, for it suggests the possibility of skeletal abridgment, a shorthand of the tune that may avoid a note-by-note comparison, without too serious a loss. Perhaps, then, at certain points, as the end of a phrase, the shape of the tune is more dependent than elsewhere on the particular note that occupies that position. In this case, phrasal cadences in relation to one another will be significant factors. Close comparison begins to bring out other diagnostic elements: how high the tune rises above its tonic, how far it falls below, within what portion of its range it is comfortably at home, and where, throughout the tune, characteristic phenomena occur. Particular features may not always seem of equal weight. Meter, though never to be ignored, seems less individualizing than might have been anticipated, but sometimes a typical rhythmic habit can be highly indicative.

Very significant is the question as to which notes of the diatonic series are employed by a tune, for these establish its modal character. In our British-American songs the occurrence of chromaticism is a suspicious circumstance. I do not mean microtonal shading, or a singer's intonation. In our older tradition, there is no modulation of the familiar harmonic kind; and it follows that every note has a meaningful, implicit reference to the tonic—most often the final note—of the tune. We testify instinctively to the tonic's latent power by our surprise when a tune ends on another note. Equally significant, in our tradition, is the *absence* of a note or notes from the diatonic octave. Many of our Appalachian tunes, in the veins of which flows a deal of Scottish blood, lack one, and more often two, notes of the scale; and of course the position of these gaps, in relation to the tonic, is as important melodically as, in other tunes, is the *presence* of the particular notes that fill them.

The melodic benefits of folk song stemming from these simple but numerous differences are greater than its harmonic deprivations. For, besides the four favorite (seven possible) heptatonic modes, our tunes may make use of six hexatonic and five pentatonic modal patterns, each of which to a sensitive ear has its own distinctive capabilities. Our folk song, this amounts to saying, is closer to the medieval *variety* than to the modern *simplicity* of major and minor with chromatic blurring, repeated at differing pitches. And something of that ancient feeling, and emotional response, for modality must have filtered down in a tradition that still prefers these patterns to the familiar sun and shade of today's major and minor. It is not a question of merely pedantic interest, for those persistent, instinctive reactions must antedate and underlie all the quaint theorizing that runs from Plato down almost to the eighteenth century in music of the Western world.

How specific the semantic meaning of the modes was felt to be in an ordered universe where every note of the terrestrial diatonic scale had its counterpart above in the planetary spheres, and where these influences, still echoing adjectivally as martial, mercurial, saturnine, or venereal, were palpable on earth in humors, bodily organs, in days of the week, hours of the day, so that the whole universal system may be said to have been full of sympathetic vibrations and celestial overtones—how specific may be readily illustrated in a quotation, contemporary with Shakespeare, and useful to today's professors of musical therapy:

> The Dorian *Moode* [writes Dowland, the great lutenist] is the bestower of wisedome, and causer of chastity. The *Phrygian* causeth wars, and enflameth fury. The *Eolian* doth appease the tempests of the minde, and when it hath appeased them lulls them asleepe. The *Lydian* doth sharpen the wit of the dull, & doth make them that are burdened with earthly desires, to desire heavenly things. . . . Every habit of the mind is governed by songs.

The wealth of modal possibilities can be pictured in a seven-pointed star that also exhibits interrelationships between modes (Fig. 1). Each point stands for a distinct heptatonic scale, the initial letter indicating its postclassical name, as Ionian, Mixolydian, etc. At the angles between the points hexatonic scales are indicated, each of which shares all its notes with the heptatonics on either side—when all three are pitched on a common tonic or "keynote"—and therefore assigned a double initial. At the innermost angles are the pentatonic scales, numbered π^1 to π^5. Each of these, lacking the semitones that differentiate the fuller scales, shares all its notes with the hexatonics and hepta-

tonics to which the diagram connects it. Typically, a tune made out of the notes of any one of these schemes has its individual feeling and quality because of the position of gaps, or of semitonal notes, with relation to the basic note (tonic) of the tune. But, because of the scalar correspondences indicated, the pentatonics are, so to speak, the common denominators by means of which a tune may pass most easily from one mode to another in the chances of oral transmission. The

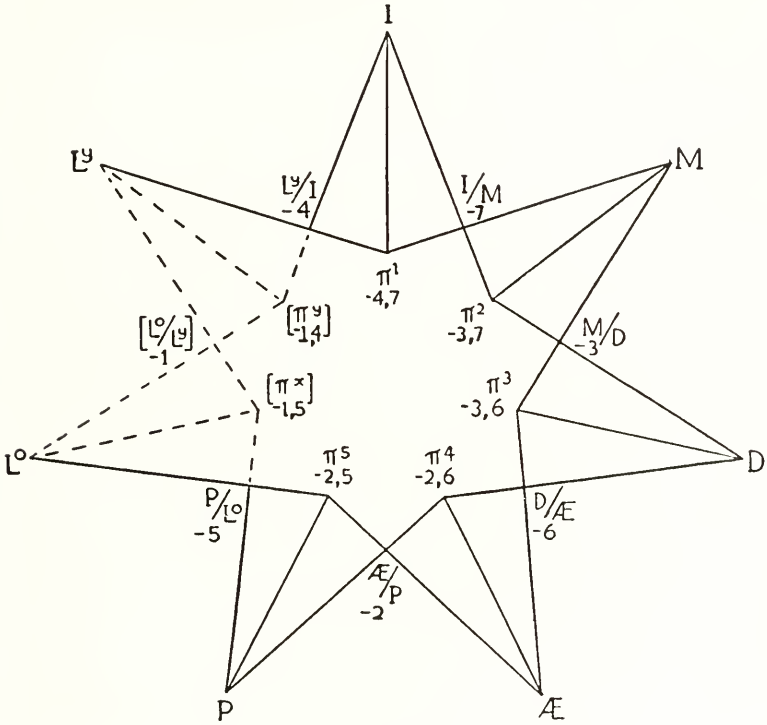

Fig. 1

passage may occur naturally and even unconsciously; but it may also take place by means of a plagal-authentic shift effective throughout the system, that connects the modes in a more organic way. It will be seen over all that there are eighteen legitimate modal patterns—of which, however, our tradition habitually repudiates three.

If we are to keep track of all these data in a large, comparative study, we shall find ourselves staggering under a load of statistics so multifarious as to be quite unmanageable and indeed discouraging. For we may want to take out and study in various correlations any of the elements or factors noted in our search for norms. It seems time,

therefore, to cast about for some means of controlling the oppressive mass of detail. In this extremity, it naturally occurs to us to inquire of those electronic robots, clothed in power and magic, which speak with sibylline utterance in our day and which can answer the hardest questions in the twinkling of an eye. Might they not be entreated on our behalf to idle away a vacant moment in aesthetic relaxation? After all, we shall not need the thunder and lightning of the greater gods.

Fig. 2

All we ask at present is a little counting and a few correlated statistics. A mere "drudging goblin" would almost do our business.

Looking intently at the familiar IBM card (Fig. 2, *A*) with a hopeful eye, it dawns upon us that those serried ranks of figures on dress parade can just as well stand for the degrees of a musical octave as for less Pythagorean entities. Since with a double punch to the column they translate into letters, we could use the first eight letters of the alphabet, if we wished, for a higher octave, and the middle series for a lower (Fig. 2, *B*). Three octaves would more than cover the vocal

range we need. Taking only the stressed notes, of which in a typical tune in our folk tradition there are normally four to a phrase, we could register the skeletal outline of eight such phrases on less than half the length of a card. Elsewhere a punch could indicate which modal scale was being employed, and space could be saved for noting accidental sharps or flats. The rest of the card could be given over to whatever data we thought important to tabulate. With some initial experiment, we might come to the Oracle with an interpretative card looking like this (Fig. 3, *A*). Registering the desired data for a single tune, with the punches interpreted in alphabetical and numerical symbols, we should have a result that could be easily read, as here (Fig. 3, *B*). But of course the Sibyl understands the punches as readily as our familiar letter and numerical languages, and the punched card, like this (Fig. 3, *C*), is all she needs to answer the sort of questions we have in mind.

Armed, then, with a pack of cards on each of which is punched the information about a single tune to be collated in statistical comparisons, we approach the Sacred Grove. Once admitted, and doffing our sandals, we ask the Priest such questions as the following: Say, an it please thee, how many tunes lie in the authentic range, how many in the plagal, how many extend through both? How many share the same melodic mode, and which are they? Is there a correspondence between the mode in which they are found and the region whence they came? or the region and the metrical pattern? Pray collect all tunes with a mid-cadence on the same degree and say what the probability is of the corresponding first phrase cadencing on a particular degree. We entreat thee, arrange in order the linear identities of tunes, by accented notes from the beginning, as far as identity goes; and tell us also where the most frequent correspondences lie over all. So may we learn the points of greatest stability in that ideal image of the tune which exists in the collective mind of the singers, and begin thence to deduce that abstract copy, or paradigm, "toward which the whole creation moves."

It could not be that the god would send us away empty-handed. We emerge, in fact, with a pile of folded sheets in exchange for our cards. What is stamped on the sheets might look like the specimen before you (Fig. 4), the order from left to right being arbitrarily determined. The order downward answers also to a series of factors of predetermined, graduated importance.

Supposing, to give specific illustrative point to our generalizations, we had elected to focus on that most familiar of all ballads in English, "Barbara Allen." Supernatural assistance has not, alas! enabled us to anticipate and analyze the versions of the present company. Instead,

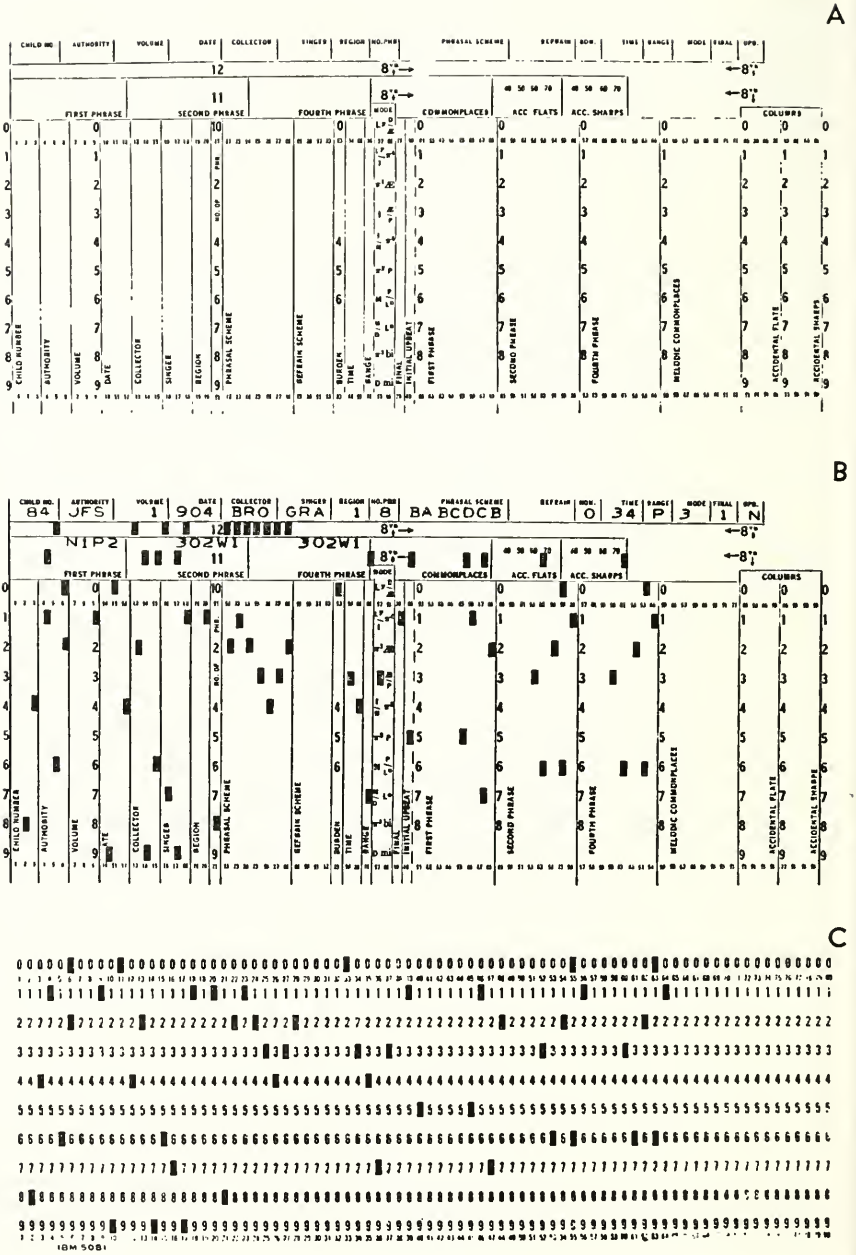
A
B
C
CHILD NO.
AUTHORITY
VOLUME
DATE
COLLECTOR
SINGER
REGION
NO. PHR
PHRASAL SCHEME
REFRAIN
NOV.
TIME
RANGE
MODE
FINAL
UPD.
FIRST PHRASE
SECOND PHRASE
FOURTH PHRASE
COMMONPLACES
ACC. FLATS
ACC. SHARPS
COLUMNS
CHILD NUMBER
AUTHORITY
VOLUME
DATE
COLLECTOR
SINGER
REGION
PHRASAL SCHEME
REFRAIN SCHEME
BURDEN
TIME
RANGE
FINAL
INITIAL UPBEAT
FIRST PHRASE
SECOND PHRASE
FOURTH PHRASE
MELODIC COMMONPLACES
ACCIDENTAL FLATS
ACCIDENTAL SHARPS
84
JFS
1
904
BRO
GRA
1
8
BA BCDCB
0
34
P
3
1
N
NIP2
302W1
302W1
IBM 5081

FIG. 3

we have been obliged to scour through libraries, comb collections, both printed and manuscript, of various dates, and transcribe phonographic recordings of sundry kinds, in order to amass a comparable body of evidence—two hundred-odd copies of the song. By this search, we have at least added a spatial and a temporal dimension to the evidence.

In brief, what the sibylline leaves seem to say—for oracular responses are seldom crystal clear—is that the tunes of "Barbara Allen," with

84CJSS	904SHA	PAL	1	4BCD		066A3	1	1	1551	6A7W5			
84CJSS	906SHA	LOC	1	4BCD		054A3	1	5	A6A6	A87W5			
84CJSS	907SHA	LOC	1	4BCD		054A3	1	5	A6A6	A87W5			
84CJSS	906SHA	STO	1	4BCD		054A3	1	1	3311	6A7W5			
84CJSS	906SHA	GRA	1	4BCD		054A3	1	1	3411	3A7W5			
84CJSS	905SHA	LAC	1	4BCD		054A3	1	1	3441	6A7W5			
84 WC	2859CHA		1	4BCD		034A3	1	1	3531	3A7W5			
84EFR	850RIM		1	4BCD		034A3	1	1	3531	3A7W5			
84 CF	55			4BCD		034A3	1	1	3531	3A7W5			
84CJSS	921SHA	RIC	1	4BCD		034A3	1	5	3541	6A7W5			
84JIF	1904FOX	CAR	3	4BCD		066A3	1	1	3531	68TW5			
84WTM	926MAC	LAN	20	4BCD		044A3	1	1	3831	4A7W5			
84CJSS	916SHA	MAC	25	4BAC		032A4	1	5	6543	322W1			
84JFS	7924CLA	CRE	1	4BCD		032A4	1	1	3152W1	4465			
84CJSS	906SHA	SAY	1	4BCD		054P1	1	N	11PN	333W2			
84 PBS	91 BAR	COB	21	4BAC		044P1	1	5	311N	123W3			
84 RS	926SMI	COM	25	6BABCDCB		024A5	1	0	1425	652W1	652W1		
84JFS	1904BRO	GRA	1	6BABCDCB		034P3	1	N	N1P2	302W1	302W1		
84JFS	1904BRO	VAI	1	5BCDE	5	034P3	1	N	102N	P33W2			
84CJSS	906SHA	CHA	1	4BCD		054P3	1	N	3310	153W2			
84 PBV	91 BAR	WIL	21	4BCD		044P3	1	1	33NN	343W2			
84 FK	891KID	WAR	1	6BCDCD	56	034P3	1	N	1321	13PW2			
84 FK	891KID	HOL	1	4BCD		034P3	1	N	13P4	13PW2			
84 PBV	93 BAR	HAR	21	4BCD		034P3	1	N	13P4	13PW2			
84 CS	927SAN	DAV	29	4BCD		066P3	1	N	13P4	13PW2			
84CJSS	906SHA	STO	1	4BAC		066P3	1	N	121N	53PW2			
84CJSS	905SHA	DUR	1	5BCDE	5	054P3	1	N	1300	22PW2			
84EHL	939LIN	HAR	21	4BCD		044P3	1	3	332N	N54W3			
84CJSS	907SHA	CHA	1	4BCD		054P3	1	N	3310	165W3			
84 PQS	906GRA	HOR	1	4BAC		0X6P4	1	5	6311	623W2			
84MOE	939EDD	HOU	23	4BCD		034P4	1	N	131N	514W2			
84CJS	1932SHA	SLO	26	4BCD		032P 0	1	1	1541	141W3			
84CJS	1932SHA	HEN	26	4BCD		032P 1	1	1	1551	141W3			
84 CO	925GRE	QUI	2	6BABCDAB		044A6	A	C	5355	535WA	535WA		
84PWJ	912JOY		3	4BCD		044A5	1	5	3131	535WA			
84 CO	925DUN	GIL	2	4BCD		034P5	1	1	3541	P31N			
84 CO	925GRE	JOH	2	4BCD		044A 0	A	7	ACD8	AA5WA			
84 JJ	3790JOH		2	4BCD		044A 0	A	5	AC7D	AC5WA			
84 CO	925DUN	GIL	2	4BAB		044P 0	1	N	1N32	1NPW1			
84 WC	1876CHR		2	4BCD		034P 0	1	1	3131	3514			
84 WC	1876CHR		2	4BAC		034A 2	1	3	5A57	5AAW5			
84 WC	1876CHR		2	6BCDCD	56	044A 2	A	5	ACB8	ACSWA			
84BNE	10935BAR	FRE	21	4BAC		034P 6	1	2	2NON	N3NW1			
84 DS	937SCA	CAL	25	4BCD		034A3	1	5	5AA4	5AAW5			
84 PBS	907BAR	CLA	22	4ABC		044A6	1	5	5AA5	5AA5			
84AKD	929STO	DAV	25	6ABCBC	56	044A1	1	5	6663	6663			
84 VR	1946RAN	MCC	24	4ABA		032P 1	1	P	1441	1441			
84 VR	1946RAN	MCD	24	4ABC		034P 0	N	N	1431	143W1			
84MOE	939EDD	DAR	23	4BCD		044A7	1	4	5A75	5A7W6			
84HAB	940BEL	CHA	24	4ABC		034A7	1	4	5AA5	5AAW5			
84HMB	940BEL	CAS	24	5ABCC	5	044A7	1	4	5AA5	5AAW5			
84JHC	925COX	BAR	25	4ABC		044A7	1	4	5AA5	5AA5			
84AKD	929DAV		25	4ABC		044A7	1	5	5AA5	5AA5			
84CJSS	917SHA	SLO	26	4BCD		044M7	1	1	5751	5755			
84JAF	22905BAR	HAL	22	4BCD		034A7	1	4	45A74	45A7W5			
84CJSS	917SHA	TOW	26	4BCD		044A7	1	4	5AA4	5AA5			

FIG. 4

negligible anomalies excepted, fall into four rather unequal groups, members of which are found on both sides of the Atlantic with varying frequency. One class is mainly English, consistently major and heptatonic, and divided about equally between the authentic and plagal ranges (Fig. 5, *A*). Many variants, especially in southwestern England, lean to 5/4 time (Fig. 5, *B*). The over-all shape of examples in the authentic range is from tonic to dominant and back to tonic in the first phrase; rising in the second phrase to the octave, but falling back from the seventh degree to the fifth for a middle cadence. The

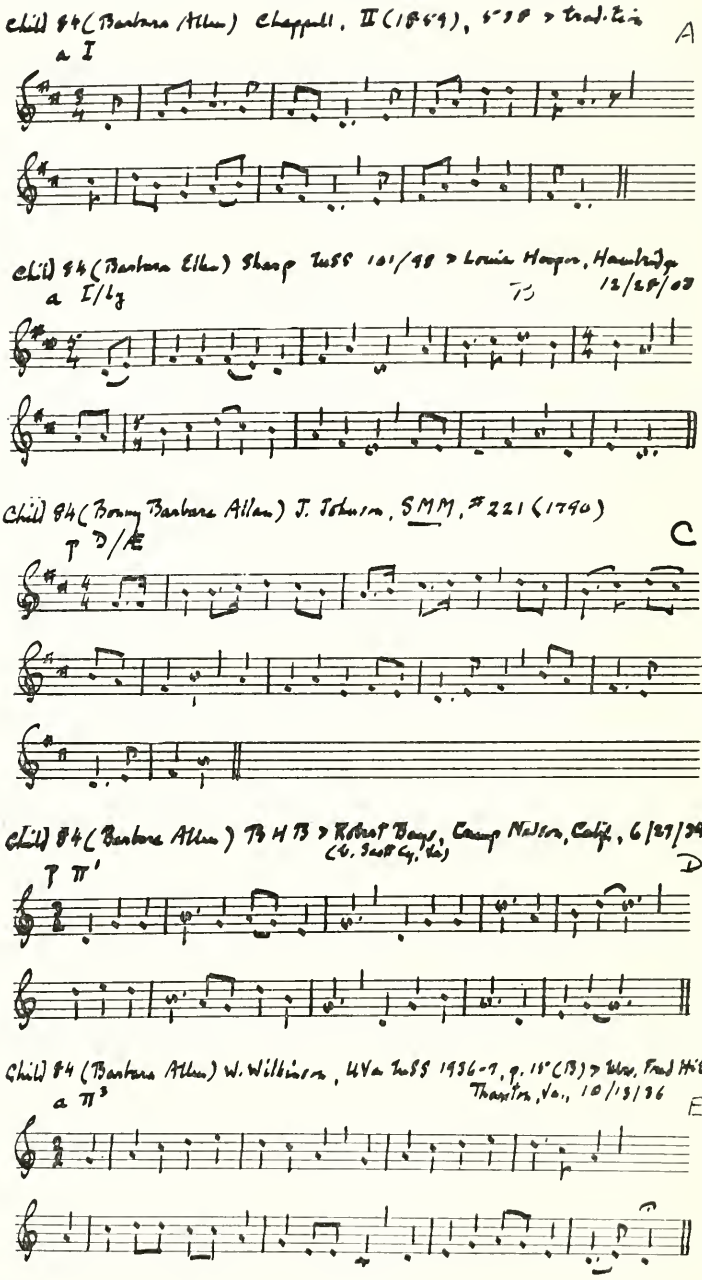
Child 84 (Barbara Allen) Chappell, II (1859), 538 > tradition
A
a I
Child 84 (Barbara Allen) Sharp MSS 101/98 > Louise Hooper, Hambridge 12/28/03
a I/by
Child 84 (Bonny Barbara Allan) J. Johnson, SMM, #221 (1790)
C
p D/Æ
Child 84 (Barbara Allen) B H B > Robert Bays, Camp Nelson, Calif., 6/27/34
(b. Scott Cy, Va)
D
p π'
Child 84 (Barbara Allen) W. Wilkinson, UVa MSS 1936-7, p. 15 (B) > Mrs. Fred Hite, Thornton, Va., 10/13/36
E
a π³

FIG. 5

melodic curve of the third phrase is often rather like the second; and the fourth resembles the first, but seldom closely, so that the phrasal scheme is generally ABCD.

Another class is mainly Scottish, with a darker modal cast, from Dorian to Aeolian (Fig. 5, *C*). It favors common time, often commencing with a dotted meter; and it typically rises at the middle and final cadences from the lower fifth or flat seventh to the tonic.

A third class, which includes many American variants, is habitually in that pentatonic scale which lacks the fourth and seventh degrees (Fig. 5, *D*). Its members are mostly plagal tunes, frequently in 3/4 or 3/2 time. Its most consistent features are a rather chaconne-like rhythm, and a middle cadence with a feminine ending that rises like a query from the major third to the fifth degree. The query is answered in the musical rhyme of the final cadence, typically from lower sixth to tonic.

The fourth class is composed almost entirely of American variants of a tune that goes back at least to the seventeenth century. Whether its origins are Scottish, Irish, or English is uncertain. Its usual form nowadays is only the second half of the ancient double-strain tune; and the final makes a rather dubious tonic without the missing half to rationalize it (Fig. 5, *E*). The middle cadence of the remaining half commonly falls from the octave or seventh to the fifth. This class is composed mostly of pentatonic tunes lacking their third and sixth, but there are also a good many hexatonic variants lacking only their third. Over all, the first and third classes have perhaps a good deal in common, while the Scottish, or second group, is the most distinct—though it has affiliations with other songs than the "Barbara Allen" tribe. The fourth class, too, is of frequent occurrence in other connections.

But we must not forget that "Barbara Allen" is a song; and all this while the words have been left languishing. Returning, then, to the text, we may ask first whether the welter of change, "each way in move," shows any traces of a *current* of tradition; and whether, against "the everlasting wash of air" and the ever present erosive action of forgetfulness, which alters while it gradually obliterates, there stand out harder substances that resist destruction, or if perhaps there may even be re-creative forces at work.

At the start, the name of the place where the action occurs has clung in memory with surprising tenacity. "Scarlet Town," which is not to be found on any map, and which may even be an inspired corruption of a known locality, has stood firm in the popular imagination. Reading (town), for which it might once have been a punning substitute, has not been taken up, nor has London, though they both occur sporadically. But place has often thinned to vaguenesses

like "in the town," "in the west country," or "way down South"; and where the localizing impulse has grown so weak, it has tended to drop out, usually taking with it the line which emphasizes Barbara's local potency: "made *every* youth cry wellaway."

Two contrasting seasons for the central event have made strong claims to permanent acceptance: autumn and spring. Autumn, the time when green or yellow leaves were falling, was the choice of the first surviving Scottish version, of the early eighteenth century. Whether the Scots have a special weakness for the pathetic fallacy has not been determined. Burns, we recall, protested its absence:

> Ye banks and braes o' bonnie Doon,
> How can ye bloom sae fresh and fair?
> How can ye chant, ye little birds,
> And I sae weary fu' o' care!

At any rate, the opposite choice has been greatly preferred, perhaps because it sharpens the pathos, the poignancy, of the death of young lovers:

> All in the merry month of May,
> When green buds they were swelling.

Analysts suggest that the reason most suicides occur in fine weather is because of the clash between that and the private unhappiness.

The lover's name has never been felt to matter: it could be Green, Gray, Grame, Groves; and Jimmy, Willie, Sweet William, or just nothing at all. But Allen in some form has clung through thick and thin, being built into rhymes and echoed in the melodic cadences. Better rhyming has sometimes prompted "Ellen"; and thereupon the first name may become an epithet, "barbarous." But that word is rather too literary, and Barbara has generally held her ground.

The reproachful death bells have seldom been forgotten, even in regions where one may suppose bells to be rare; and sometimes, to clinch their message, they have stirred up a chorus of birds to the same import. But when even the birds say "Hard-hearted Barbara Ellen," bells are no longer needed, and sometimes are forgotten.

To make a good ending, Barbara's remorse and death used, as the earlier texts indicate, to be judged sufficient. But not latterly: familiar formulas from other songs have suggested themselves, and the conclusion is drawn out at length. Barbara orders her mother to make her bed, her father to dig her grave; if Jimmie dies as it might be today, she dies as it might be tomorrow, of love in the one case, in the other of sorrow. They are buried in churchyard and choir, respectively, and the old favorite rose-and-briar ending, symbolic or, as some say,

metempsychotic, is appended. Frequently the metaphor fades, and the briar springs from Willie, the rose from Barbara. What matters is that they twine in a true-love knot.

A fact that seems to have escaped attention is the very interesting metamorphosis which has befallen Barbara herself in her lifetime. Tradition has gradually transformed her, subtly but surely, without much conscious assistance from anyone. This characteristic process is worth a closer look.

The first known reference to the song's existence is in Pepys's diary, January 2, 1666, when, at end of a very long day, that indefatigable man hurries off in the evening to my Lord Bruncker's, where he finds a numerous company—"but, above all, my dear Mrs. Knipp, with whom I sang, and in perfect pleasure I was to hear her sing, and especially her little Scotch song of 'Barbary Allen.' " How much older the song may be we cannot surely say, but the frequent mention of old songs, like "Greensleeves," in earlier literature makes the lack of a single casual Elizabethan allusion to Barbara an argument for a mid-seventeenth-century origin. Pepys calls it a Scottish song, and Mrs. Knipp, like Maxine Sullivan some years later, may have picked it up and given it an urban currency by singing it on the stage. It has even been wildly conjectured that the song was a covert attack on Barbara Villiers, Countess of Castlemaine. We have no Scottish text so early; no recorded tune in Scotland for another century, in England for two centuries. But an English broadside text was printed in London in Pepys's own day, and its most salient features—with powerful assistance from Percy's *Reliques,* a work continually reprinted after 1765—have been perpetuated in the traditional memory. "Barbara Allen's Cruelty," it was called, and unexplained cruelty was her chief characteristic trait. It has been a main business of tradition to rationalize this quality and explain it away. In the broadside, when the young man's servant comes to summon her, she ruthlessly replies:

> If death be printed in his face,
> And sorrow's in him dwelling,
> Then little better shall he be
> For bonny Barbara Allen.

This *anticipative* obduracy, inessential to the narrative, has disappeared from the popular mind, though her reluctant and tardy arrival is remembered:

> So slowly, slowly she got up,
> And so slowly she came to him,
> And all she said when she came there,
> "Young man, I think you are a dying."

In the broadside, his appeal for her pity is met by the retort:

"If on your death-bed you be lying,
What is that to Barbara Allen?
I cannot keep you from your death;
So farewell," said Barbara Allen.

So stony a heart was too much for the popular sensibility, which went to work on motivation. In the earliest Scottish copy, printed about fifty years later, in Ramsay's *Tea Table Miscellany*, and also reprinted by Percy, she is not cold but bitterly resentful:

"O the better for me ye's never be
Tho your heart's blood were a spilling.

"O dinna ye mind, young man," said she,
"When ye was in the tavern a drinking,
That ye made the healths gae round and round,
And slighted Barbara Allen?"

In the Scottish copy, he has no reply, but turns his face to the wall with a kind adieu. She leaves the deathbed with visible reluctance and a parting sigh, and goes home to announce her imminent death.

Not so the early broadside. Walking "on a day," Barbara hears the death bell, turns round to see the funeral procession, orders the corpse to be set down, and takes a long look, all the while loudly laughing. Again the popular mind has recoiled, and in copy after American copy, we find verses like these:

The more she looked, the more she grieved,
She busted out to crying.
"I might have saved this young man's life
And kept him from hard dying."

Sometimes self-reproach changes even to self-exculpation:

"Oh mother dear, you caused all this;
You would not let me have him."

Thus, little by little, and partly through mere abridgment and condensation, a kindlier, more sympathetic image has been wrought in tradition. If Barbara was once a "real person," as Phillips Barry believed that she must have been, she has certainly mellowed with age!

"Barbara Allen" is unquestionably and by all odds the best-known, most favorite traditional ballad among English-speaking peoples in the twentieth, and like enough the nineteenth, century. This is a curious fact, and one not very easy to explain. By ordinary standards, one must acknowledge that the story has few of the elements that make a

smash hit. The action is far from violent; there is little suspense in it, and a minimum of surprise. The "hero"—if he may so be called—is pallid in every sense: he is acted upon, and hardly acts at all—unless to throw up the sponge in round one constitutes an act. For although he pleads he is misunderstood in some variants, far more of them have no trace of his defense; yet the song flourishes. There is no love triangle, no defiance of conventional morality, no struggle, no complication, no delay. Where is the heroic spirit of the common man, the indomitable will to live, come what may? Here is neither hope nor courage: only abject surrender. As the first choice of the English-speaking peoples, it is a strange phenomenon.

The psychological problem—and I think it is a real one—must be consigned to the experts. But before we leave it, we may remind ourselves that the idea of love as a destructive power has been a potent concept for almost as long as the records of Western civilization can be traced. By the ancients it was looked upon as a seizure, a calamity, a madness; and the lover's madness was a disease also well known to the Middle Ages. In all early literature, as in the best-loved ballads, love is an illness from which few or none recover. Because of it, Barbara's lover is doomed. Her own observation is as clinical as cruel: "Young man, I think you're dying." But what she does not as yet realize is that the disease is infectious. After her rash exposure, *her* death is almost equally predictable, and imminent. She can do nothing to avert it: Love strikes unerringly where he will, and "caught is proud and caught is debonair." "But these are all lies," protests Rosalind cynically: "Men have died from time to time, and worms have eaten them, but not for love." It may be true—but we wish they had! Truly, we wish they had. The ideal of a love so complete and entire as to be essential to the continuance of life is a conceptual archetype persisting through the ages, through all literature, the greatest—and the least. While we scorn the spinelessness of Barbara's lover, some ray of this compelling magic touches him and transfigures him at last; and Barbara herself is redeemed by the *Liebestod*.

To descend to more humdrum matters. I think we may lay it down as axiomatic that whatever is under no external necessity to be remembered will be forgotten if it is possible to forget it. Survival depends partly on ease of recollection. In this sense, "Barbara Allen" is an extremely memorable song. It is next to impossible to get the narrative twisted. There are but two characters, and they are at once delineated by word and act in crisis. The heroine's name is not only unforgettable by virtue of syntactical management but itself serves as a mnemonic for the stanzaic rhymes, calling back the successive phases of the narrative: dwelling, swelling, telling, knelling; while the dou-

ble rhyme is its own reminding device, requiring special heed and a matching musical cadence to parallel and reinforce it.

So we return once more to the tunes, which are the vital element in which the story exists—the air it breathes, and the breath of its life. We find, when we extend our correlation of the tunes to a comparative analysis of the whole body of most common and typical British-American folk tunes, that those of "Barbara Allen," in spite of superficial differences and casual exceptions or anomalies, fall into the central norm of our tradition (Fig. 6). They act as we should expect

Frequency Counts of ABCD Tunes of Seven Most Popular Ballads
(Child Nos. 4, 12, 53, 73, 84, 200, 243)

Authentic Tunes (277)

←SCALE—DEGREES / ACCENT—POINTS→	1	2	3	4	5	6	7	8
4			2	1				
3		4			1	3		
2		1	3	2		11	7	
1	9	60	30	3	28	140	43	23
VII	1	5	11	1	15	18	52	5
VI	8	11	13	3	37	19	37	7
V	92	80	60	32	105	29	101	112
IV	41	38	42	38	32	37	11	2
III	76	27	59	15	21	11	17	4
II	4	13	34	7	3	4	7	18
I	48	39	23	172	28	5	2	6
VII	1			3				
VI								
V								
IV								
III								
II								
O					7			

Mixed Tunes (73)

	1	2	3	4	5	6	7	8
1		1	1	1	2	6	4	
VII		37			1	38	3	1
VI		1	2		15	16	3	1
V	42	6	46	1	40	7	45	65
IV	2	1	4	1	5	1	3	1
III	12	14	2	3	3	3	13	1
II		3	10	6				2
I	15	7	7	59	4		1	1
VII	1	1						
VI		2	1	1	1	1		
V	1			3			1	1
IV								
III								
II								
O					2			

Plagal Tunes (165)

	1	2	3	4	5	6	7	8
VI		3	1		2	8	1	1
V	10	12	5	4	21	70	23	66
IV	2	3	15	3	11	19	22	10
III	24	60	14	1	46	26	63	17
II	1	9	37	12	5	14	28	59
I	111	61	54	57	69	20	16	4
VII		4	17	3	1	3	8	1
VI	3	6	14	5	3		2	3
V	14	6	7	78	4	4		3
IV		1	1	2				
III						1		
II							1	1
O					3			

FIG. 6

them to do, and require no extra will-to-remember. They end on the tonic, their mid-cadences are usually at the fifth. Their rhythms are simple and familiar. Their length is the common four-phrase length; their phrasal patterns are habitually progressive, ABCD; and in their individual shapes the phrases are typical. Their ranges stay within normal bounds; their melodic modes are among the commonest: major or near-major pentatonics, or (for Scotland) Dorian/Aeolian.

These normal likings gain their importance from being so widespread and universal in our traditional culture. Things need not have gone this way; they might have turned out otherwise. To make these the prevailing patterns, there had to be an infinite number of rejections, conscious or instinctive, or alternative choices or different ap-

peals. Thus, in the long course of time, racial music traditions tend to establish their idiosyncratic distinctions and habitual characters. The psychological and aesthetic implications of these musical facts are far-reaching and profound. When someone asks, why all this fuss and bother, this endless trouble and expenditure of time on an old song, the answer is: because this old song, in its mere, sheer *commonness*, strikes to our very roots. There is no obligation on these old things to survive. They have lived on in the minds and hearts of countless men and women, untainted by compulsion, for the purest and most disinterested reason possible to be conceived: because they have continued to give joy and solace, on the basic levels of artistic experience, to generation after generation of our humankind. "The proper study of mankind is man"; and so long as this precept remains valid, folk song will continue to be an important subject for human inquiry.

NOTE: What is said above of "Barbara Allen" echoes and expands the summary statement on this ballad in the author's *Traditional Tunes of the Child Ballads*, II (1962), 321. Figure 1 has already appeared in the same work (p. xii) and earlier in the *Musical Quarterly*, XXXII (1946), 44. Figure 6 was printed in the *Journal of the International Folk Music Council*, IX (1957), 27.

JOHN LYON REID

The Climate for Design

I AM PLEASED both personally and professionally by the opportunity to talk to you on an occasion as important as this. It is my hope that the inclusion of an architect in an otherwise distinguished panel of speakers representing such a wide spectrum of human interest and activity is recognition of the many-sided significance of architecture in our lives and in our culture.

I want to talk to you about architecture, but not as a professional critic. Rather, it is my intent and hope that I may find in our architecture something about ourselves, and I would also like to raise the question whether or not there are ways through which we may prepare ourselves to achieve a better environment than we now have. My opinions are limited to what we are doing in the United States.

First, we probably should define some of our terms. We regard architecture as one of the indicators of civilization and the ability to produce good architecture as one of the skills of a civilized man. Architecture and civilization are inseparable. In addition to the many pleasures that architecture affords to the informed student, it also reveals to him an understanding of the people who produced it and the circumstances under which they worked. It is interesting that we can study the architecture of the past, and draw conclusions from it, with a familiarity and assurance that we cannot always summon when we study the architecture we now produce for ourselves.

The term "architecture" is usually understood to apply to a building, but this is unfortunately too narrow a meaning to serve my purposes here. I would prefer to regard "architecture" as meaning the total pattern that man creates on the earth's surface to sustain him, to provide for him, to shelter him, to allow him to travel, and to express

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what higher aspirations he is moved to express. I think the architect of today may be considered as presumptuous when he regards all these as being the "architecture" he has produced, but there is, of course, some historical precedent for his presumption. The Piazza of San Marco in Venice, the plaza in front of St. Peter's together with the whole Vatican complex, the architect Haussmann's plan for Paris, all give some substance for this enlarged view of architecture.

The architect in the most limited definition of his craft is one who concerns himself with the design of a building, large or small. The architect of today is commissioned to design a fraction of the total of the buildings that are constructed, and this is unfortunate, although it is true that he does design the large ones, the public ones, and usually the important ones. The aggregate of all the buildings, whether designed by architects or not, gives form and substance to the environment that is both a setting for and a symbol of our life.

The opportunity that exists for the architect to participate in the shaping of our environment when he designs a single building is limited but real; but even then he often finds himself showing a concern for the effect of his building on its neighbors and on its community. In recent years he has more frequently been given the opportunity to plan developments that include more than one building, and this requires the solution to problems of vehicular traffic, utility systems, landscaping and land conservation, and the community uses of land and natural resources. The scope of his work is growing in ever widening circles. He is beginning to look with a professional, although a skeptical, eye on such problems as the design of the entire land and water area of San Francisco Bay and even to such planning problems as the vast regional community extending from Boston to Washington, D.C. When I talk of architects in this sense, I mean the whole professional spread of those who participate in the planning of our environment, not alone those who are licensed to practice architecture. I suppose the use of the word "architect" in this way is almost as broad as when we say that Winston Churchill was the "architect" of Britain's war strategy.

We have become quite accustomed, with the help of historians, to acquainting ourselves with the people of many historical epochs by examination and study of the architecture they produced. An examination of the architecture we are producing today, no matter whether we take the more limited view of the single building or the enlarged view of the fabric of the region, is not completely reassuring. If we examine critically the larger environmental complex, we are entitled to expect that the same principles of aesthetics might well apply to a region as apply to a building, and that a design incompetence which

is regional in scale is no more tolerable than when it occurs on a single building. But regardless of the scale of the work, our competence to create it, to invest it with some degree of aesthetic content, and our sensitive awareness of this content are measures of how civilized we are.

I have assumed that all of us would agree that most of our urban complexes, when viewed as a whole, are not as well designed as we would wish. It is only recently that any conscious attempt has been made to plan their rehabilitation and growth, and it is too soon to be critical of what architects and planners have been able to accomplish. But so often high property values, traffic habits, and shortsighted business interests have increased the difficulties and reduced the chances of the best solutions being reached. We have had little experience in seeing a community grow over a period of years in accordance with a good plan, and so we find it hard to visualize the amenities that would come out of it. I am afraid that too many Americans accept as inevitable the many disadvantages of the typical city.

It has been one of my professional privileges for almost the last two years to serve the University of California as consulting architect on one of its many campuses, that of the University of California Medical Center in San Francisco. We are starting now on the preparation of a master-plan study for the campus, and an Academic Planning Committee is one of the participating committees whose responsibility is to guide the development of the curriculum into the future so that it will serve as one of the bases for the master plan of physical facilities. I have been impressed by the statement of objectives of the medical profession as formulated by this committee. This committee has told me that years ago the medical profession believed its responsibility to be treatment of disease in the individual. Over the years this was changed so that the profession addressed itself to the cultivation of health in the individual. A more recent change now says that the doctor holds his job to be the investigation, treatment, and adjustment of all factors in man's environment so as to sustain man in a state of maximum health. Thus the interest of the medical profession is now enlarged to cover not only its patients' intellectual and physical activity, but also their problems of community sanitation, housing, urban noises, smog, traffic, food, and virtually everything that touches the patients' lives. This interest of the profession, which I point out is somewhat an aesthetic one, and which is certainly directed toward the larger architectural environment, gives strength to the architect's solicitude about the same thing.

It is my belief that the quality of our architectural output as measured by many standards, of which the aesthetic is of first importance,

is not quite as good as our advanced civilization would otherwise lead us to expect, and, unhappily, I believe that only a cultural elite seems to be aware of it. I think that it is appropriate to ask whether or not we are capable of creating a civilized environment for ourselves.

It is interesting, I think, to probe the reasons for this. The answer is not to be found alone in the competence of the architect or in the competence of his professional planning and engineering colleagues. The citizenry as a whole, the people the architects and planners work for, participate in the creation of architecture to a degree never before known. I have often wondered whether the architectural greats of a previous generation were able to do their creative thinking and work in an artistic isolation, where, like the artist-painter, they had only to answer to their aesthetic and intuitive dictates; perhaps they did not enjoy such enviable freedom. Today the architect has a relatively small amount of freedom of personal artistic decision.

History has not prepared us for the kind of world we find ourselves in today. We know many times more about the world than we ever did before, and we know it with relative suddenness. We probably have not grown in knowledge and wisdom in the balanced and fully rounded sense that the whole man requires. One of the most serious handicaps to the production of a moving, satisfying, and civilized architecture is the lack of common roots, of a tradition, of a shared body of knowledge and culture that unify and strengthen the people that the architect serves, if a worthy architecture is to be produced.

Dr. Robert Oppenheimer addressed the annual convention of the American Institute of Architects in 1960. He presented some statistics and said hesitantly that these data were not altogether new. They were new to some of us, and to all of us they were disturbing.

He told us, for instance, that measured by any quantitative standard at all, such as by the number of people involved, or by the amount of publications appearing, or by the number of patents issued, scientific activity has doubled approximately every ten years during the last two hundred years.

Since Dr. Oppenheimer spoke in 1960, a person even with my experience in the simplest forms of arithmetic can calculate that if only one scientist were alive in 1760, today there would be 1,048,576 living, working scientists. If there were two, today there would be 2,097,152.

Further, he told us that approximately 90–93 per cent of all the scientists who had lived and worked in the entire history of civilized man are alive and working today. He said that we knew four times as much about science in 1960 as we did in 1950. Through some of the

sciences having to do with molecular microbiology, we had gained more insight into the nature of life itself during the preceding five years than had been previously accumulated in the entire history of man. In the field of human behavior, we are moving at a much more sedate pace, since today we only know twice as much as we did twenty years ago.

Such information is disturbing to us because of the terrifying acceleration it reveals in the expansion of our knowledge. The rapidity of this growth is producing such a prodigious total that it is getting farther and farther out of the reach of the majority: whether or not we can master this knowledge and use it for our higher purposes is a good question. The gravity of this question does not, however, slow up our pursuit of more knowledge; we are here to celebrate fifty years of effective leadership by Rice University in contributing to the solution of this problem.

I completed my undergraduate work and graduate work at the university level about 1930, and my degrees were evidence of the fact that I had accumulated a few facts and had been able to retain them at least until the appropriate degrees had been conferred. I am sure that these facts I acquired were intended to serve me over a certain period of time, which was never stipulated exactly, nor could it be. In addition to that, it was assumed that I had an attitude of inquiry and an interest in acquiring more knowledge, and a respect for it. All this would help form my attitude toward life, its problems and opportunities. I assume, too, that those who decided in their wisdom that I had earned a degree felt that in some way I showed the beginning of a development of my own philosophy, an awareness of the problems and travails of myself and of my fellow man, a hope and an eagerness on my part that I might contribute to their solution, and a belief in the importance of that contribution, no matter how meager.

Some of those facts that I had accumulated decreased in importance or lost their validity much sooner than I had anticipated, and, I am sure, sooner also than anticipated by my universities. A man may now expect that he will be required to renew himself four times in his lifetime if he is to keep his stock of facts current.

This represents one of the major problems of those who engage in a life of intellectual activity, and I suspect that there are more people today than ever before who live, work, and produce through activities that are substantially intellectual. The so-called three learned professions, law, medicine, and theology, have not for a long time defined the limits of the intellectual life.

The productive potential of the machine has for some years been affecting our lives and making its changes in our ways of living.

Lewis Mumford believes that one of our major problems stems from our inability to master the machine. Be that as it may, the machine has not only assisted us in the search for knowledge but now drives us to seek more. The time that it has given us has freed a greater percentage of people than ever before to search and inquire.

More knowledge and the limits of the human mental capacity lead us, whether we like it or not, to specialization. For most of my own life I have been superficially familiar, at least, with the problems of the medical specialist. My brother-in-law is a surgeon, and I have been conversationally exposed to his problems for thirty years; recently my work with the University of California Medical Center has permitted me to listen to discussions of the problems of educating the doctor. We hear of the specialties of the eye, the blood, the allergy, the virus, the brain, and the gland. It is recognized that the treatment of the whole man and his health cannot be handled by an accumulation of specialists; and this has led to the emergence of another specialist, the diagnostician. This situation has a direct effect on the cost of achieving and maintaining health, and the doctor is fully aware of the dilemma he and we face. The elimination of the specialist is not necessarily the answer, particularly if we are to pursue the complex and related chains of knowledge that are accumulating. The age of the specialist is not about to end but, if anything, to intensify.

And that presents one of the major dilemmas of contemporary life. Our knowledge, it seems, is being developed by those who have only an indirect communication, if any at all, with the man upon whose life their knowledge has such an impact. This is true in an age where the technique of communication has reached at the present time a high level of development. Man has traveled around this world in ninety minutes, and we are now talking about a commercial transportation service to carry a man from New York to San Francisco in about one and one-half hours. The present figure of four and one-half hours was a dream a few years ago. We can now transmit live television pictures from Europe to America. I have talked with ease on the telephone between Algiers and San Francisco. The problems of 150 million are now the problems of two and one-half billion people.

While the physical instruments of communication are being constantly developed and improved, there seems to be a gap in intellectual communication that is not bridged. That gap is measured in terms of the limits of the individual capacity and our mounting fund of knowledge. One man can't know everything there is to know, and we cannot help him by stopping the search. Not only will his curiosity urge him, but the scientific tradition will encourage him to penetrate deeper and deeper into the field of his interest. The continuing quest for

knowledge offers a trap of esoteric specialization which is difficult to avoid as our knowledge deepens. The more we find out through specialized research, the more we become aware of the bonds which interrelate all knowledge. The dissolving of the barriers between the fields of knowledge does not simplify the problems which our high degree of specialization creates for us.

The term "Renaissance man" probably did not originate during the Renaissance, but rather appears today as we begin to sense our own inadequacies to synthesize our stockpile of facts into a philosophy that has meaning and pertinence for us. Leonardo da Vinci is the name that first comes to mind when we think of the "Renaissance man." He was no doubt possessed of incredible intellectual powers and must be recognized by everyone as one of the great artists in our Western tradition. He was a sculptor, a painter, an architect; he was a naturalist, a geologist, a chemist, a mathematician, and an astronomer; he was a maker of musical instruments and a musician; he engaged in metalwork, he made jewelry, he studied anatomy, and he was a designer of pageants. He was a writer and a poet. There is some evidence that he knew something about weaving and that in his younger days he was a strong man and an athlete of sorts. He was an expert in the arts and weapons of war. Because of his work and studies the aircraft of today would not be an unexpected sight for him.

Even with his knowledge of scientific matters, he probably today would be regarded as a dilettante and a dabbler. I doubt if even his powers of intellect would permit him today to penetrate as deeply into as many fields of knowledge as they did in his day. It did not require an intellect of Leonardo's stature to acquire a sufficient mastery of the knowledge of the times to synthesize it into a philosophy that was necessary to act with skill, grace, and even intellectual reward in the life of the day. With the evidence we now have of the breadth and depth of Renaissance civilization, I would assume that an elite existed in some numbers that possessed a meaningful philosophy of life and some mastery of man's range of knowledge. Today this is infinitely more difficult, if not impossible, for even a smaller elite.

It appears to me, then, that today we have an unfortunately narrow band over which we can communicate. The scientist or the engineer, whose work may have a great impact on the life, the habits, and the thinking of all of us, can with difficulty, if he can at all, interpret his work to the man in the street. That this is so seldom done must not be overlooked as one of the causes of the tensions and maladjustments of the contemporary scene. At those times in the history of civilization when man has felt that he was capable of leading a civilized life and was leading it, there was a capacity for communication and an un-

derstanding that was broad, at least, in terms of the dimension of man's knowledge at the time. The peak of Renaissance civilization as we know it showed a constructive and creative activity in the political life, where people not only participated actively in it, and I presume with intelligence, but sustained an interest in their government and themselves. These and the affairs of the market place and world of the arts are all a part of a life of intellectual vigor and challenge that requires a comprehensive insight into the structure of the whole society by its citizens.

If the extent and complexity of our knowledge have created serious problems, their positive contributions are so obvious and so significant that they should not be diminished by a one-sided view of the whole matter. Poverty, want, and hunger have come closer to the vanishing point than at any time in history. In their place we have achieved an abundance that is a problem in itself and a standard of comfort, choice, and service in our day-to-day life; the prospect of continually increasing leisure we hope will not be a problem. All these, if we are able to shape them into the structure we want for society, hold tempting prospects.

One of the most serious problems of the architect today is the meagerness of this bond of common interest, of these roots and traditions, and of this area of popular commune. The architect, with his eye on the civilization he is helping to shape, is too often unhappy and dissatisfied with the results of his professional efforts and seeks reasons for it. Although there are many distinguished buildings in the United States which have been built in recent years, the percentage seems to him to be too low. The architect does not like the environment, both urban and suburban, that is emerging; he wishes that more people would be constructively dissatisfied with it. Architecture and the total environment of which it is a part are measures of our intellectual stature and symbols of our artistic maturity or immaturity. The architect hopes that between him and his fellow citizens, the nonarchitects, there would exist a common interest, a tradition, an avenue of communication that would enable them jointly to create a more fitting total environment. If the quality of architecture today is something less than we deserve, it is regrettable. When it is a barometer of intellectual and artistic maladjustment, it is even more regrettable.

The architect today does not have the strength, the independence, the authority, or, for that matter, the wisdom to design a civilized environment singlehanded; the structure of society instead delineates relationships which virtually require action by groups to do the job.

The difficulty the architect faces is made of two parts: first, that architecture as it has significance for us is a work of art and as such is

the creation of an individual; and second, that the temper of the times inclines us, even forces us, to group action. Our reverence for the democratic process does not dispose us to confer on the artist the right to make artistic decisions, especially when they are personal ones, and especially when they shape a public architecture. Whether or not democracy can be made to understand the artistic process is a moot question. The more culturally enlightened the members of a democratic society become, the greater, I am sure, will be the understanding of the artistic process and the greater the willingness to let the artist be an artist.

For the present, at least, architecture is produced by a rather remarkable process of group action. Let me describe for you a few of the specifics and the particulars of this group effort as I have seen it and some of the problems that the architect and the citizen face, as together they give form to our environment.

In my own professional work I have had the opportunity to design a great many public school buildings, where the client has been the public, represented by the school board. This board is composed of a cross section of the community, and members come from the professions, from business, and from the home. A school building in some ways is a mirror that with the least distortion reflects the expression of community desires and intent. To me, school buildings and churches are unusual and special challenges to an architect in that the design can be resolved only in part on grounds of function, cost, and time schedule. These three things invariably arise as criteria for school buildings, since they are easy to understand and to handle in a public discussion; and, too, I do not deny their importance. Especially in these two types of projects, there are design overtones which are for the architect the nature and the essence of the problem and of the challenge. Without being at all sentimental about it, the architect likes to think when he is designing a school building that he is offering a sound and businesslike answer to matters of function, cost, and time schedule, and also that he is planting in a community a symbol of education expressed in concrete and steel, which shows the importance of education and which stands in some mystical way as an emblem of faith in children and hope for their future. And, of course, these latter are ultimately the only measures of value.

I suppose that it is quite unrealistic of me to say that altogether too few public communities have recognized this challenge that so many of my architect colleagues have seen in the design of school buildings; too few value a completed school building for those things that make it an inspired answer to this challenge. Most school buildings in America that have been built in the last fifteen years are adequate and certainly

better as educational instruments than those that were being built in 1900; some of them are distinguished, and a very few of them are inspired. I would like to raise the percentage. To improve our schools now requires only two things: a desire to improve them and a common agreement on what an inspired school building might be. The first, the desire, is not the subject of this talk. The second is; the breadth of knowledge, a common understanding, a tradition that would unite an architect and a public for creative accomplishment. This is not often found and, I repeat, is the greatest deterrent to a distinguished architecture that I know today.

Recently the federal government authorized a nationwide competition to select a design and an architect for a memorial to be located in Washington, D.C., to Franklin Delano Roosevelt. When the results of the judgment of the competition were announced there were heated debates regarding the winning designs, and these debates occurred not only within the profession but with equal enthusiasm and heat in the press and among the public in general. At the present time, I believe, congressional hearings regarding the competition, the judgment, and the winning designs are still in progress. It is my opinion that there will not be sufficient agreement among all of the lay and professional people involved to permit the project to be built. I am not at all hopeful, even, that the present public and professional climate is such that a monument of this importance could ever be built.

The public shows itself in many different ways as it exerts its influence on architecture. In the public school building and in the Roosevelt competition, the participation and the voice of the public is firsthand and direct. It may show itself in a much more indirect way where state rules, regulations, and administrative procedures embody habits, attitudes, and, in some cases, obscured objectives. The public influence on architecture may show itself in ways that are usually perceived by architects and by few others because of the purely professional and specialized nature of the involvement; the public, not being involved as a first party, is seldom aware of the strength of its influence on design. For instance, the urban environment, particularly in that part of it that is built by private capital, is shaped by a myriad of influences which are not strictly architectural and which in this sense are public, such as tax laws, considerations of property value, zoning laws, building codes, legal controls, and advertising necessities that are overwhelming and bewildering to the lay person and little short of it for the architect. Out of this man-made complexity, we probably could not at the present time create a civilized environment, even if we wanted to. This complexity of laws and regulations and

the lack of common goals and enlightened standards must carry a large responsibility for today's architecture.

Too seldom will a public client be strongly moved by common goals, and too often will chances for success go down the drain in the conflicts and compromises of group action. Any project that successfully survives all this faces further hazards at the state level. The state of California has produced a formidable body of rules and regulations which govern the design and construction of public school buildings and which may require during the course of a project 147 approvals of public agencies before the completion of construction. We are more fortunate in Texas, where only about six are required.

The architect often finds himself working on large and important commissions with a corporate body of one kind or another as the client. It is interesting that some of the corporate enterprises of America show sophistication and enlightenment, and they build distinguished buildings in both urban and suburban settings that set high standards for their communities. This is quite obviously not due alone to the quality of architectural service they employ, since one corporate body will often employ several architects, each working separately on different projects, where all the results are good. This has happened with enough frequency that one wonders whether or not a small group of well-educated men (could I call it a "cultural elite"?) in the corporate management was responsible for the results and what produced the elite group.

Today the architect does his work most often in varied kinds of collaborative efforts with varied public bodies. Less frequently does he work with the individual client. There are notable exceptions, however. I knew an individual with an intense interest in creative design who occupied a position of authority in a corporate structure, and who found himself able to provide a leadership that attracted and encouraged the finest kind of creative artist; Walter Paepke of the Container Corporation of America was such a person. But most often the forces that are so important today in their effect on artistic expression, on architecture, and on our environment as a whole are those that arise from the activities and policies of the organization rather than the discriminating individual.

Automobiles today owe their appearance to stylists—specialists who carry out the findings of a public opinion poll, which is interpreted to them by the public relations department; I suppose that this shows that the public has now taken over the design of automobiles and has superseded the automobile designer-craftsman. The architect so far has been able to show a little more strength in his tussle against public taste.

To recapitulate for a moment a few of the things we have talked about: (*a*) For many reasons which are unique to the times in which we now live, we find it increasingly hard to share interests, to understand each other, and to communicate. We are separated, not enriched, by our differences. (*b*) If we look for it, we can quite easily see this in our architecture, because (*c*) the artistic, intuitive, and personal choices of the individual architect which are necessary to a distinguished architecture are becoming less important in the creation of today's architecture than the influences, both direct and indirect, which arise through public participation. (*d*) If I am right in thinking that a distinguished architecture is desirable and that it can be achieved; if I am right in attaching great importance to the public influence and participation in the creation of our contemporary architecture; if I am right in thinking that we will not find our best in architectural design until our common bonds are strengthened and deepened. . . . then what next?

To proceed: It is of little consequence to question which is more important, the architecture which has failed as yet to reach its potential high-water mark or the cultural inadequacy it reveals. I am sure that there is little disagreement that both are important, and the climate in which architecture reaches its full flower will similarly nourish our cultural growth.

Among the many strengths of our society, public education is probably the greatest. It probably involves more individuals than any other single effort we make. The operations of the national educational effort are not reserved for an elite segment of our people, but rather touch in varying degrees almost everyone. The effectiveness and the methods of our educational system have received and are receiving a great deal of attention and criticism. I cannot help but say, parenthetically, that much of it is unfavorable and much of it is uninformed and unfair. We are quick to blame our educators for our inability to match immediately every Soviet accomplishment, for the alleged physical unfitness of our armed forces, for juvenile delinquency, and for the national crime rate, and I suppose it would be consistent to hold our educators responsible for what I believe to be a palpably small bond of common intellectual ground that holds our nation and perhaps our civilization together. It is my belief, and one that I hold with conviction, that public education is far less responsible for this than are we as a whole, that educators are aware of this problem and have been attempting to cope with it with what I believe to be encouraging success. If this success is more limited than we would wish, it can be attributed rather to the national temper than to the ineffectiveness of education. This is a problem, however, that I think can

only be solved by education, and it must be dealt with at all levels of education, not alone in the universities.

When I was on the faculty of the Massachusetts Institute of Technology, I remember the deep concern that was felt about the responsibility of the Institute to educate the whole man, and I remember the decision to form a School of Humanities to broaden the educational experience of the students in what then seemed to me a most unlikely place, an institution devoted so completely to science and engineering. So many institutions at the university level offering specialized and professional training now give increasing emphasis to the humanities. I see the greatest hope for the solution of the problems I have attempted to describe by attaching even more importance than we do now to studies in this field. The scope of our knowledge today is vast indeed. How do we assimilate it, understand it, and make it serve us?

In relatively recent years man has shown a spectacular skill in the fields of science and engineering which has yielded the even more spectacular accomplishments which are the symbols of our time. If we are less skilled and less accomplished in the arts, I think it can be linked to the weakness of the cultural bond that holds us together. It seems to me that the great task which faces education today, and particularly at the university level, is a twofold one: to encourage and to implement the pursuit of knowledge no matter how deep or esoteric the penetration into the unknown; and to broaden and elevate the level of human discourse, to strengthen our roots and the traditions common to all of us, to extend to the widest conceivable dimension the band over which the intellectual, artistic, and humanitarian interests of all people extend. The second, particularly, presents to the universities a task and a challenge of greatest importance.

SIR GEORGE PAGET THOMSON

Fifty Years of Physics and Their Consequences

When Rice Institute was founded, physics was a very flourishing subject academically. The discovery of the electron was fifteen years old, and, fully accepted, it had already had a profound influence. It was some years since J. J. Thomson had been described as "the man who split the atom." The phrase has been applied to more than one person since, and with increasing truth, for J. J.'s split was only a chip, and not permanent at that, since atoms that have lost electrons recover them. It was natural for those responsible for setting up an institution which was to be first rate both in teaching and research to look for a man from the Cavendish Laboratory at Cambridge, England, where so much of this work had been done. They found H. A. Wilson, the revered *doyen* of your staff, who even then had already done much, both to measure the properties of individual electrons and to show how they explained the conduction of electricity in flames.

But although so exciting to physicists, the subject had comparatively little impact on the life of the world. It had indeed furnished the fundamental discoveries which made possible first the electric telegraph and then heavy electrical engineering and telephones, but electrical engineering had split off from physics and, though there were contacts over radio, they were not extensive. The "modern" physics had indeed affected medicine, principally through X rays, used mainly diagnostically, and radium, used in the treatment of cancer.

The invention of the airplane had revived interest in the mechanics

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of fluids, until then a very academic subject with little relation to reality. It did not even explain how an airplane could get off the ground. It was transformed during and after the First World War by the realization of the vital importance of turbulent motion, even in cases such as a well-designed wing, where there is little apparent sign of it.

The First World War brought a certain change both in the United States and in Britain in our attitude to science in general, which acquired a practical importance so far unsuspected by the average citizen. However, chemistry in the form of high explosives and poison gas was more prominent than physics, which was mostly concerned with acoustic methods of locating guns and submarines. Nevertheless, governments took action after the war and set up bodies designed to favor the development of the applications of science, including physics; for example, the National Research Council in the United States, the Department of Scientific and Industrial Research in Britain. They found plenty of physics to apply in the rapid discoveries of the following years.

In the time at my disposal I can obviously only touch on a few of the more dramatic discoveries of the period.

The electron, as I have said, was well established, the quantum theory had been put forward by Planck twelve years before, but the strangeness even of the original idea that energy can only be transferred in discrete packets had prevented its being widely accepted. Most people thought that there was something in it—it certainly gave the right answer for what is called black-body radiation and for the energy of electrons released from metals by the ultraviolet light, but there was probably some less drastic explanation. However, it had believers and missionaries.

Max von Laue's discovery of the diffraction of X rays allowed Sir William Henry Bragg and his son, Sir William Lawrence Bragg, to refound the science of crystallography. As the result of fifty years' work, the ways in which the constituent atoms are packed into crystals have been discovered for tens of thousands of substances of slowly increasing complexity, culminating in the work of M. F. Perutz and J. C. Kendrew on hemoglobin, whose structure is built up of units of some six thousand atoms (not counting hydrogen), arranged in curious twisted patterns: the biological applications of X-ray diffraction are likely in the future to be even more important than have been those to chemistry and metallurgy in the recent past.

In 1912 the idea of a heavy nucleus at the center of each atom, which Ernest Rutherford had put forward two years before, was fairly well established. In 1913 Niels Bohr used it in his model of the

hydrogen atom in which an electron was supposed to describe orbits round the nucleus and which was also the first successful attempt to apply the quantum theory to the emission of light by separated atoms, as contrasted with the close-packed atoms of a solid. Bohr's was a strange theory indeed, admittedly not completely logical, and with a curious nonrepresentational element in it—for the electron was supposed to jump from one orbit to another without spending time in between. The reaction of physicists was a little like the reaction of the present day to Picasso. Some frankly refused to accept it, others thought it might be made acceptable by some change, others again accepted it with enthusiasm as a great step forward and looked for the next move. For those who accept the analogy with art, I might mention that Bohr's theory has indeed been greatly modified, but that the changes have made it, on the whole, further from common sense than it was to begin with! This should not surprise us. Advances in science, at least the really great ones, generally imply an idea which at first sight seems absurd. What could be sillier than to suppose people living on the opposite side of the earth with their feet directed toward us? Obviously they would fall off! Or a little later, to suppose the earth rotating and moving with great speed round a sun at rest, when obviously it is the sun that moves?

This paper of Bohr's was followed after the first war by an exciting decade when the principal interest in physics lay in finding out how electrons behave in the atom, mostly by the use of the spectroscope. It was the period when nature seemed stubbornly perverse, when Sir William Bragg uttered his famous phrase, "Light behaves like waves on Mondays, Wednesdays and Fridays, like particles on Tuesdays, Thursdays and Saturdays, and like both on Sundays." The solution came from the theories of Prince Louis de Broglie and Werner Heisenberg, which were developed by Erwin Schrödinger and Max Born into what is now called wave mechanics. To solve the paradox required a more deep-seated change than most people had supposed, for not merely was it necessary to recast all our views on light and other forms of radiation, but to change Newtonian mechanics drastically. This was clearly shown in the phenomena of electron diffraction discovered by C. J. Davisson and myself.

The main features of the outer structure of atoms, that is, the waves associated with the electrons, have long been known, though the mathematical difficulties prevent an exact solution except in a few cases. These same outer electrons are responsible for chemical affinity, and the structures of a number of chemical compounds have been worked out, at least approximately. Thus, in a sense, chemistry has become a branch of physics. The group next in size up from the mole-

cule is the crystal. I have already mentioned how the discoveries of von Laue and the Braggs led to a knowledge of the arrangements of atoms in perfect crystals. Since the last war there has been an immense amount of work done on the crystalline state of relatively simple substances such as the metals, but going into greater detail than the mere arrangement of the atoms in gross, and considering on the one side the more detailed properties of the substance, such as electrical conductivity, and on the other the consequences of irregularities in the atomic arrangement. These may be due either to impurities or mechanical misfits. It turns out that these irregularities control some of the most important properties of solids, for example, the mechanical strength. It may be possible to produce crystals with ten, twenty, or more times the tensile strength of the same substances as normally prepared. Transistors are another important example of the effects of small abnormalities in the arrangement of atoms in crystals; in this case, it is very small amounts of certain impurities, reckoned in parts per billion, in particular substances which make them work in this way.

While quantum theory was being applied to the outer atom, Rutherford and his school were leading in the study of nuclei. Rutherford observed in 1919 the first disintegration of a nucleus due to causes outside itself, namely, that of a nitrogen atom struck by an alpha particle from radium C, and other examples followed rapidly. Sir John Cockcroft and Ernest Walton in 1930 for the first time split nuclei by particles which had received their energy by the methods of ordinary electrical engineering, thus inventing the first of the "atom-smashing" machines. In 1932 Sir James Chadwick discovered the neutron. The study of cosmic rays led Carl David Anderson in the same year to find the positron, which had been predicted theoretically by Paul Dirac. Finally, in 1939 the work of Otto Hahn and Fritz Strassmann led Otto R. Frisch to prove that nuclei of uranium can be split into two roughly equal halves by neutrons. In addition to the two main pieces, free neutrons are released; a chain reaction releasing large amounts of energy became a tempting possibility. The results of yielding to this temptation are too well known for me to have to refer to them, but it is worth remarking that the strictly scientific importance of nuclear fission is somewhat limited; it does not compare in fundamental importance with Chadwick's discovery of the neutron, still less with, for example, Michael Faraday's of electromagnetic induction. Yet it has had more important practical consequences in the twenty-three years since its discovery than any other in thrice the time. Leaving these aside, and also all the exciting discoveries made since the war of the still unexplained "fundamental" particles, I should like to spend

the rest of my time discussing some consequences of the other discoveries I have so drastically condensed.

They lie in two main spheres, that of thought and that of action, with a special connecting link between the two in the form of the electronic computer. Take first the sphere of thought. The influence of science on the thought of its age has been great but uneven. During the period of Copernicus, Galileo, Descartes, and Newton it was profound. Then came a lull until the end of the eighteenth century, when the new ideas of chemists like Priestley and Lavoisier and the discovery of current electricity by Galvani and Volta accorded well with the changing political thought of the time and perhaps helped the changes. Then another lull until Darwin. The idea of evolution itself is a lasting force, but the post-Darwinian discoveries have not as yet greatly changed the popular opinion, though most people talk freely of genes and mutations.

The discovery of the electron had some popular *réclame* but little immediate effect on thought. Relativity came into popular view immediately after the First World War, though, in the limited form now known as the "Special Theory," it had in fact been developed a decade before and was pretty generally accepted by physicists when the war started. The "General Theory," for which Einstein was almost entirely responsible, came out in the middle of the war and was hardly known even to physicists until peace came.

The very marked influence of these theories on popular thought is curious and interesting, for to some extent it rests on a grammatical ambiguity. Most people took them to mean that everything is relative and that absolute standards, in morals, for example, have no validity. Apart from the great risk there must always be in giving weight to an analogy between physics and morals, this is not what the theory teaches. It is a theory "of" relativity in the sense in which one speaks of the principles "of" war, that is, the underlying ideas to be used in conducting a war, not in the sense in which the word is used in the phrase "the principle of self-government," which, if accepted, implies that self-government is a good thing.

The theory in fact discusses how the observations of one observer will change when the events observed are seen by another observer moving with respect to the first. Actually, it starts with the premise that fundamental laws in physics must be of such a kind, and expressible in such a way, that they are valid for *all* observers. On this view the fundamental laws of physics are *absolute*.

Nevertheless, relativity does assert the absence of a privileged observer. How far this is reasonable in view of the experimental identity between rotation measured mechanically and by astronomical obser-

vation may, I think, be questioned, but it is what the theory says. The theory of relativity is the last of a series beginning with Copernicus in which the center of importance has shifted from the earth to the sun, from the sun to the galaxy, and now to nowhere in particular. Special Relativity makes time intervals and space intervals between the same two events different for different observers, only a certain relation between them being invariant. General Relativity extends this to accelerations.

Relativity is the last of the old physics; the quantum led in the new. It profoundly modifies the idea that the universe is at bottom deterministic, which science has held since Newton and indeed before. On the quantum theory, all one can in principle predict about an observation of nature, or an experiment however carefully conducted, is not a definite conclusion but a series of probabilities of different conclusions being found. Atomic physics becomes like a series of horse races: the odds on each horse are knowable, but not who will win in any particular race.

Now that embryonic physicists hear of the quantum theory almost as soon as they do of Newton's laws, it is difficult for them to imagine the revolution in thought which this change implied, or the vigor with which we fought against it. There is, or was then, a school of thought which held that the laws of physics are largely a construction of the human mind, a language in terms of which the phenomena can be described, and as there are many possible human languages, so there are many equally good descriptions of physical events. To some extent this is true, but there are limitations. Atomic physics simply will not fit into the Newtonian system. It was not for want of trying. We had all been brought up with an almost religious faith in Newtonian mechanics as the fundamental verity. Relativity somewhat shook this faith, but in fact the alteration required was not very great; mass and energy are found to be the same thing, but this is an extension of the Newtonian idea rather than a denial. The quantum theory is far more revolutionary, far more disturbing; not merely does it deny determinism, but the entities which it demands have no parallels in common experience. An electron is not simply a tiny sphere of electricity, though for some purposes it is. But suppose that electrons strike a screen with a tiny hole in it: a few will go through and, if you put a photographic plate behind the screen, the electrons will blacken a small patch where they hit it. Now make a second hole very close to the first. You expect to get two black patches instead of one, and so you do, unless the holes are so close together that the patches would *overlap*. But then, instead of one blacker patch, across the region of overlap there are white lines where there is no blackening. The ef-

fects of the two holes have canceled one another out along these lines.

Those who have experienced this change of outlook are cautious, unwilling to accept the merely probable as certain, or an apparent contradiction as conclusive disproof. We know how apparently cogent arguments can break down, how statements true over a wide range of conditions have their limitations.

While all this applies to atomic processes, the theory is framed in such a way that it does not normally affect the behavior of massive bodies. For these, the conclusion given by Newtonian mechanics is almost infinitely more probable than any other; this is a consequence of the smallness of Max Planck's constant h, which determines the scale of the theory, so to speak. Only for electrons and atoms is the theory normally of decisive importance.

But the word "normally" is important. One can devise arrangements by which the effect of the passage of a single atom can be magnified indefinitely. A Geiger counter, for example, could be set to trigger a megaton bomb, and the counter in turn could be activated by the natural disintegration of a single one of the nuclei in a small speck of radium. This is a quantum effect, a matter of pure chance. Thus if one chose the amount of radium to give, say, one effective disintegration every ten minutes on the average, the bomb might quite well go off only two minutes after switching it on or not for half an hour. There would be no possible way of deciding in advance. Of course, this is a very special device which would not occur in nature, but nature produces organisms which as a result of evolution are delicately balanced so that a very small change in the brain determines the behavior of the whole. I do not know if it is yet possible to estimate the smallest physical change which would alter the behavior of a brain, human or animal: probably our knowledge of the mechanism of the brain is not yet good enough. This change might be small enough for quantum effects to be important.

Even apart from these possible biological trigger effects, there is much in the world which is indeterminate in the sense of being unpredictable and likely to remain so for all time. Max Born has discussed the relatively simple case of a gas and shown that, considering the motion in the gas of a single recognizable atom, for example, a radioactive one in a nonradioactive gas, fantastic accuracy in the initial data would be required even on Newtonian mechanics to make even a very short-term prediction. On the strict Newtonian view, however, one could say that the motion is *in principle* predictable. The quantum theory forbids this. Even for quite short-term prediction one finds that an accuracy in the initial data exceeding that permitted by the quantum theory would be needed. The distinction between

a case such as this and those I spoke of before is that here the value of Planck's constant hardly matters. It could be a billion times less than it is without making much difference provided it were not identically zero.

There is one great class of phenomena to which a similar argument applies: cases of instability. If one takes, for example, a fine fiber of glass, as uniform as possible, and stretches it by a slowly increasing force, it will usually break at some tiny crack or some thin point or even perhaps some impurity. But suppose one eliminates all weak points as did the maker of the "one-hoss shay," the fiber will still break and, unlike the shay, will not break everywhere at once. The point of breaking, if everything else is ideal, will be determined by what is called a thermal fluctuation; the atoms in one small region will acquire a heat motion in excess of the normal, and accordingly that part will be weaker. Such thermal fluctuations are unpredictable.

I have dwelt at perhaps excessive length on this aspect of the quantum theory because, though the theory has been accepted for a third of a century in pretty much its present form, its implications for indeterminacy are not fully realized outside the world of physics. For the ordinary affairs of life, if either accuracy or long-term prediction is required, determinism is probably the exception rather than the rule. A statistical prediction is usually all that is now possible, or ever will be. So we believe.

Turning now, very briefly, to the effects of fifty years of physics on the world of action, I shall omit, as I have said, what is probably the largest, the effect of nuclear energy. It is so well known there is nothing I can add in a few minutes.

The next biggest contribution comes from what is now called electronics. This name covers a variety of physical principles discovered at a variety of dates. One of the most important instruments, the cathode oscillograph, is only slightly varied from the apparatus with which J. J. Thomson discovered the electron. The transistor depends on the discovery of John Bardeen and William Shockley sixteen years ago, and between the two comes work on photoelectric cells, on thermionic emission, and on the devices you call tubes and we valves. Though electronics has important uses in heavy electrical engineering, the greater part of its use is in conveying information, whether to ear or eye or to some piece of electrical machinery, and using this information to control the behavior of something. It is the nervous system of automation, whether of factories or satellites, and of all schemes for distant control, but I believe its most important application is the electronic computer.

The electronic computer is essentially a labor-saving device. It

does nothing new, nothing that cannot in principle be done without it; and you may wonder that I should rank it, as I do, as a more important advance than putting a man into orbit. But turn your thoughts back five hundred years to the invention of printing. The printed book was no better than the manuscript, not so good as the best of them, but it could be produced in such numbers and so cheaply that it not merely revolutionized the book trade but made possible a whole host of productions, such as the daily newspaper, impossible without it.

The same is true of the computer. Its mathematical ideas are of the simplest, only addition and subtraction, but, because it can repeat these millions of times a second, it can perform calculations which would not otherwise be practical. Further, it can be made to use the result of one calculation to decide what it is to do next. For example, if the answer to the first comes out even, it can be programed to follow sequence A, but, if the first answer is odd, it will follow sequence B. This implies that its actions are conditional on what it has found and are unknown in advance by the man who set it up, though not unpredictable if he took the trouble to do all the calculations.

The applications of these computations are extraordinarily various, from making out wage sheets to the most abstruse calculations in nuclear physics or in the orbits of satellites. There is hardly a branch of human activity where they are not either actually in use or soon will be. If a theory is logically definite, its consequences, even its complicated consequences, can be calculated. This often enables the engineer to replace more or less intelligent guesses with certainty in his designs. It is likely to have important consequences in economics, and, again, the applications of physics to biology to which I have referred would be hardly possible without it. Dr. Claude Shannon, who is so much better qualified than I, will be speaking tomorrow of its use in automation.

The invention of the steam engine, though it did not increase the skill of the workman, multiplied enormously what his skill produced. That of the computer, though it does not improve men's intelligence, will enormously increase the use that can be made of that intelligence.

In contrast to nuclear energy, space travel, the other great engineering advance of our age, depends on principles which Newton would have understood without difficulty. The principle of the accelerating rocket is a direct consequence of his laws of motion, the orbits described in space are as he calculated in his *Principia*. Rockets are probably older than guns, and the Congreve rockets were seri-

ously used in war more than one hundred and fifty years ago. You remember "the rockets' red glare." There has been considerable improvement in the propellant, but not to a revolutionary extent. The main advance since Benjamin Franklin's time is in materials and in automatic devices. However, the use that can be made of the projectile, the extent to which it can be guided, the information it can record and in particular send down—all these depend on refinements in electronics, together with, of course, the electromagnetic waves which J. C. Maxwell predicted and Heinrich Hertz discovered long before our period.

One hopes that the importance of space travel will remain, as it is now, chiefly scientific and avoid military applications. The really exciting discoveries may well be the biological ones. Interesting as it will be to get to the moon, I regard this rather as a triumph of human courage and ingenuity than as a means of increasing knowledge, the ascent of Everest on a grand scale, so to speak. If one could get to Mars, where the astronomers seem convinced there is life, even if only vegetable, one would have information of vital importance as to the origin of life and all that implies for our ideas as to our own nature. Is life on Mars much the same as on earth, not varying more than it does on earth between, say, the Congo and the tundra, or between sea and land, or is it wholly different? If similar, how closely so? Supposing that it is based like ours on compounds of carbon, oxygen, and nitrogen, do, for example, amino acids play the important part there that they do here, and, if so, are the ones chosen the twenty or so which seem to have selected themselves in some unknown fashion to compose terrestrial proteins?

This I think is typical. Physics is a great part of science, but science is one, both as a system of thought and as a means of controlling nature; much of the future of physics lies with biology.

LOUIS LANDRÉ

A Cultural Common Market?

ONE WOULD CERTAINLY NOT VENTURE to say that the various agreements made during the last ten years between six nations might eventually turn Continental Europe into a kind of cultural supermarket in which one could find neatly packed and arranged, in one corner philosophy and musical treasures; to the south *bel canto* and an astonishing wealth of artistic realizations; in another part finesse, logic, keen psychological insight; in the center the creations in letters and art of people attentive to the realities and the very richness of life. It is all too evident that treaties affecting the output of coal and steel, the pooling together of energy, the eventual suppression of customs barriers, the production and distribution of agricultural goods could not be duplicated with any hope of tangible results in the fields of literature and the arts or in the spiritual lives of the nations concerned.

But one can recall that the exchanges in all fields between the six nations of the Common Market have been constant, that they have in common more than twelve centuries of history and civilization. They have undergone the same deep cultural influences at the start; in spite of many differences, they have come to accept very much the same cultural values, and they share an ideal, that of Western humanism. They enjoy considerable prestige all over the world, particularly through their thinkers, writers, and artists and also through their scientists and technicians; given their particularly rich past, one may deem that their intimate union may eventually lead to very happy consequences, not only for their own welfare, but for that of the whole world.

An exploration of the cultural history of western Europe, displaying its dominant themes and essential unity, while taking into con-

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sideration the originality of each nation and eventually of sections within each nation, would indeed be a fascinating task. All I can do today is to recall a few periods, certain names, a number of significant developments.

In the dark period which followed the disruption of the Roman Empire and the *Pax Romana* so beneficent to all, culture, together with work and prayer, took refuge in scattered monasteries where cloistered monks pored with reverence over skilfully illuminated manuscripts. As time went on, the continental part of the Empire became the Holy Roman (German) Empire, with indeed a rather loose link between its component parts but with a sense of its unity, especially its spiritual and religious unity, as appeared under the reign of the great emperor Charlemagne.

Another dark era followed the dismemberment of his empire. But the twelfth and thirteenth centuries witnessed the splendid medieval renascence which is by no means a purely national phenomenon: Romanesque art flourished particularly in Spain, France, and northern Italy; Gothic architecture developed almost simultaneously in northern France and Germany; schools grew in the shadow of monasteries and cathedrals. Students had gathered near Notre Dame on the left bank of the Seine as early as the twelfth century in order to listen to such famous masters as Abélard; they were grouped according to the nations they came from. These were days of a universalist civilization, strongly drawing various countries together: Aquinas, who came from Naples, studied in Cologne under Albertus Magnus before he became one of the glories of the University of Paris.

More significant still is that vast European movement, the Renaissance, which brought about an extraordinary renewal of literature, the arts, and the sciences. It started in fifteenth-century Italy, encouraged by great scholar-popes, rich cities like Florence and Rome, the old universities in Bologna and Padua. It flowered in Germany and France, then spread to Flanders and the Low Countries, and also, with magnificent results, to England. The rediscovery of Greek and Latin antiquity as the source of wisdom and artistic beauty, the study of the ancient texts, sacred or profane, in a spirit of scholarship and informed criticism were its first fruits. The discovery of the printing press by Gutenberg was to open an entirely new era in the dissemination of culture.

The Reformation, by turns partner and enemy of the Renaissance, was to bring the collapse of Christian unity, a most important fact in the spiritual life of Europe. Two remarkable figures, the vigorous German theologian Luther and the stern French scholar Calvin,

played prominent parts in the new forms of faith. The Reformation and what has been called the Counter Reformation, that is, the internal reforms brought about at that time in the Catholic church, created profound disturbances in the western European countries. But they also produced in these countries, by the heat of controversy and the stimulus to thought, the same decisive enrichment of intellectual and religious consciousness.

There followed in some countries a period of struggle and strife, as shown by the Thirty Years' War which ravaged Germany. In some countries the early sixteenth century was rather a continuation of the Renaissance. It was the golden age of the Low Countries: painting flourished in Flanders with such men as Rubens, in the Netherlands with Rembrandt and the Dutch masters, all men of energy, keen vision, and reason. Italy, together with Spain, provided many inspiring themes for literature. But the need for discipline was soon felt. About 1628, Descartes, the famous French philosopher, settled in the Low Countries: there at Leiden in 1637 came out his *Discours de la méthode* in which he explained how one should conduct one's thoughts. The second half of the century was dominated at the beginning by French classicism: thoughtful imitation of the ancients, a keen probing of the human heart, clarity and order in the presentation were keynotes of literature; the architecture of the time throughout Europe preserves under different skies the same distinctive notes of regularity and majesty. The last two decades of the century, however, saw a gradual change from intellectualism to critical rationalism; accepted ideas were more openly discussed, and more importance was given to close observation and eventually experimentation. In this great intellectual and spiritual revolution, the Netherlands through Spinoza, Italy through Vico, Germany through Leibniz, and France through Bayle—to quote only a few names—took an important part. But the influence of the English scientists, Newton in particular, and that of John Locke was predominant: England aspired to share with France the intellectual hegemony of Europe.

All those throughout Europe who were interested in literature, philosophy, political thought, and science were drawn together in a noble republic of the mind. Exchanges were free and numerous. Voltaire, a friend of Bolingbroke and a visitor to England, was cordially received by Frederick II, king of Prussia, before settling near Geneva on the French border, where many visitors called on him. It was the age of enlightenment, with considerable freedom of thought and a growing interest in experimental science and in the problems of human societies. New political and social ideas were in the air

which eventually opened the way for the revolutions of the second half of the century and much of the liberal thinking of the nineteenth. But the eighteenth century also witnessed everywhere the gradual awakening in some countries of sensibility.

The sense, often a pantheistic sense, of nature, a taste for the strange and the exotic, the love of the past—particularly the medieval past—the return to ancient legends and national traditions, an intensely personal lyrical impulse, brooding disquiet over the lot of men; such were the characteristic themes, the fresh sources of feeling and imagination which were to bring the so-called Romantic movement under its various forms. Germany led the way, revolting violently against the traditional and purely rational; then began for her a period of intense production in literature, music, and philosophy; this was the time of Goethe and Schiller, Beethoven, Kant, Fichte, Hegel; their influence was to be felt all over Europe, and for the rest of the century, at least. Frequent borrowings were made from one country to another: Madame de Staël extolled the virtues of the Germans and encouraged French writers to imitate what she called the literatures of the North. Stendhal and several French critics were to set Shakespeare against Racine.

We need not go much further into the nineteenth and twentieth centuries to show that the nations of western Europe are not only linked by geographical and historical ties, but that there is much more between them. Under their diversity, which should be preserved and even encouraged, in spite of the distinct and occasionally antagonistic spiritual families among them, sometimes in the midst of individual nations, there is an incontestable unity in their cultural history; unity, we should remember, is not uniformity. In fact, through long centuries of close associations and of numberless exchanges, they have shaped their own civilization, they have shared common ideals which ultimately have become those of the Western world and have indeed exerted a considerable influence on the whole world of today.

At this point, however, a remark—a very essential remark—should be made: the six nations we have been mostly dealing with are by no means the whole of Europe. If it is quite legitimate to stress their role, it would be absurd, and most unfair, to ignore that of their neighbors: that of hard-working Switzerland in the center of them; that of Portugal and Spain with the Moorish influences that were brought to bear on them, their part in the discovery of new worlds, their rich contributions to arts and letters; that of the Scandinavian countries in spite of their relative remoteness; that of Austria which for so long has played a decisive part in European affairs and which has produced musicians and artists; and, through Austria, of the component parts of

the Austro-Hungarian Empire, particularly Bohemia and Hungary.

If we speak of western European culture, we have no right to limit it to western Continental Europe and exclude Great Britain. A curious and touching symbol of our early intellectual commerce is Alcuin, a learned Benedictine monk from the cloister school at York, who was called upon by Charlemagne to reorganize his schools in France. Exchanges were even more frequent after the Franco-Norman invasion of 1066. The two first archbishops of Canterbury after the Conquest, Lanfranc, who started work on the present cathedral, and St. Anselm, a famous and profound divine, were Italian monks who had become priors of an important monastery in Normandy before being called to their eminent seat. In turn, John of Salisbury, a disciple of Abélard in the University of Paris who could freely quote Ovid, Virgil, and Cicero and who sang the charm of Paris, became bishop of Chartres. Literary relations between England and France had begun with the "matter of Britain" in the *chansons de geste:* the exploits of Arthur and the quest of the Holy Grail were extolled on both sides of the Channel; and the writers of both countries set forth their idealistic conceptions of courtly and of mystic love. These relations were to be continued for more than eight centuries, much to the benefit of each of the two countries. And so were the cultural relations between Britain and Italy, so frequently referred to by English dramatists and poets. Germany at times exercised a great influence on Britain, as is shown by the case of Coleridge and Carlyle. From the Netherlands, at the invitation of the unfortunate King Charles I, came great painters such as Rubens and Van Dyck.

The Continent in turn had much to learn from Britain. Its dramatists, Shakespeare in the first place, and its poets have met with considerable success and exerted a very deep influence over the Channel. The Englishman's well-known taste for close observation, well-established facts, experiment, his respect for nature and life as expressed by many British writers and thinkers (Bacon and Locke, for instance) have been a welcome counterpart to a certain amount of rigidity in Continental—and particularly French—logic. They exerted a considerable influence on eighteenth- and nineteenth-century western Europe. The role of British men of science, especially after the foundation of the Royal Society in 1660, need not be emphasized. Modern political institutions, in Europe and even more throughout the world, owe more to British theory and practice in the field of government than to those of any other nation.

The close and constant co-operation which I have tried to recall has not meant lack of communication with the outside world. Western Europe has not shut itself—and does not mean to shut itself—from the

races of eastern Europe, from those of the Slav soul and Russian fervor. It has been in close contact with Islam, Islamic science, Islamic art, and greatly enriched itself thereby. It has almost constantly sought to communicate with China behind her wall and taken advantage of what could be gained through contacts with Chinese art and wisdom. Nor has it ignored the Persian and Indian worlds, finding inspiration, as time went on, in Buddhism and the Veda.

But, when this is said, it cannot be denied that the two forces which have served to shape what we may call Western humanism, given it its proper direction and quality, inspired it throughout the ages and until today, are on the one hand the influence of the ancient Mediterranean world, mainly Greece and Rome, and on the other, Christian beliefs. In the words of a modern philosopher it was "cast in bronze by melting together in the same crucible Greek philosophy, the Latin juridical spirit and Judeo-Christian theology."[1] Hence its extraordinary richness and radiance.

Greek thought, which has inspired and is still inspiring so many of our thinkers, invited people to examine man closely, to exercise the mind untrammeled, and to study nature and the world freed from all prejudice. In addition to transmitting to the world much that it had inherited from it, Rome taught it the importance of clear, well-ordered reasoning, the sense of civil justice and the law, the blessings of peace in an organized and stable state.

The Bible and Christianity revealed the infinite worth and depth of the human soul, the essential importance of charity and love of mankind, the idea of divine power, benevolence, and justice. The Judeo-Christian acted as a leaven at the start; even to those who are detached from traditional beliefs, historically and basically, Western civilization is a Christian civilization.

The "Know thyself" of Socrates, the "Homo sum humani nil a me alienum puto" of Terence, the "I have compassion on the multitude" of the Gospels are among the key words which until today and through nearly twenty centuries have guided our civilization.

Hence, in the Western world, the paramount importance given to man: to man as an individual, as a social being, as an element in the universe. The motto of Protagoras, "Man is the measure of all things," has been described as the dividing line between two worlds. This, however, does not mean the idolatrous worship of man, but the determined resolve never, even in the boldest speculations, to lose sight of man, his condition, his needs.

Under the influence of the Greeks, special confidence has been put

[1] René Grousset, "L'Humanisme classique et le monde moderne," in *Pour un nouvel humanisme* (Neuchâtel, 1949), pp. 12–13.

in reason, as the proper attitude of man, as the secret of his methods to conduct both his thought and his action. Certain civilizations have remained at the stage of imaginative thought and mere myth-making. Western Europe, in the days of decadent scholasticism, ran the risk of falling into Byzantine subtleties and disputatious word-spinning. But it has succeeded in subtly blending rationalism of the Cartesian kind and what Descartes himself, following Bacon, described as "the art of experiments," thus achieving the happy balance of experimental reason which has been the strength of modern science and which has not excluded either feeling or imagination, as appears in many other fields of human endeavor.

From this has grown a passionate curiosity which has exerted itself in all the works of human genius, in science, technology, the arts. This indeed is evident if we consider the world's history from the twelfth century to the twentieth: science has been called the Greek miracle, and the Arabs of the Middle Ages have added considerably to it. But it was western Europe which, in the sixteenth and seventeenth centuries, gave the natural sciences their first great impetus. This was not the work of one single nation: it united a whole continent with such names as Copernicus, Mercator, Kepler, Galileo, Torricelli, Pascal, and Newton in that marvelous partnership among observation, experiment, calculation, and interpretation. Technical progress has soon followed scientific progress, since in the words of the founder of positivism, "Science begets foresight; foresight, action." Prehistoric man had invented the tool, modern man has invented the machine. Again the role of western Europe, as early as the eighteenth century, has been decisive, again the inventive genius of men of several nations has been united in fruitful collaboration.

The same remark can be made about artistic creation under all its forms. Art, like science, is indeed universal; it transfigures and enlarges life everywhere, and, in considering the arts of a certain portion of the world, it would be preposterous to forget or ignore those of other portions: the quiet dignity of the Taj Mahal or the exquisite delicacy of Chinese pottery. But from the efforts of the builders and sculptors of her magnificent cathedrals to the most feverish—and occasionally unexpected—researches of contemporary painting, from Gregorian plain song to Italian opera, or to the works of Bach, Mozart, and Beethoven, to leave out her many dramatists and poets, western Europe may be justly proud of the immense, diverse, inspiring contribution it has made and is still making to the common patrimony of mankind.

Man does not merely require food and material comfort. He is a moral being who should know how to regulate his own life and be-

have in society. In the words of a moralist of the sixteenth century, "Science without conscience is but the ruin of the soul." Today, we may—or we must—go even further, and accept the remark made by the philosopher Henri Bergson when he officially received his Nobel Prize: The body of mankind has grown, if we consider all the increase of power constituted by our machines and industrial equipment, but its soul has remained unchanged. He concluded, "Mankind needs an increase of soul." This, indeed, we could find in the works of the oriental sages, or, for instance, in the Buddhist or Moslem religions; but, not to insist on the Christian religion—which is part and parcel of Western civilization, which is, to a considerable extent, its inspirer—what a wealth of considerations upon man, his impulses and motives, his place in society and the world, and his duties can serve us in the philosophies and literatures of the countries we have been considering —that of Dante, that of Goethe and Kant, that of Molière—if we limit ourselves to the older and bigger nations; and we cannot, indeed, leave aside the thinkers and writers of the land of Shakespeare and Bunyan.

A thousand years of common history, of common intellectual and spiritual endeavor; a common ideal which has led not only to a high material civilization, that of science and technology, setting man up on the earth, but to a high spiritual civilization, raising life to a nobler plane; a constant consideration of the vital needs of man—such, we feel, are the main traits of the very rich civilization which has flourished in western Europe.

We realize most clearly that Europe is not the whole world. We recognize the immense contributions which have been made in the fields of science, technique, the arts, and literature by the descendants of western Europe—the nations of South, Central, and North America, particularly this magnificent, so active country, the United States of America. We know the extraordinary achievements in science of Soviet Russia; we understand that its present economic, social, and political organization is a challenge to the rest of the world. The Orient, where splendid civilizations have grown, is ready to play its part in the concert of nations. We understand the needs and the ambitions of the independent republics of Africa.

It is interesting and encouraging that, just at this point, six of the nations which have done so much to shape the ideal of the Western world and which have exerted so much influence in the world should be united by close bonds. At this point indeed one may raise two sets of objections:

1. That the treaties signed concern only six nations, that these are not all of Europe, that there may even be danger in the formation of

such a "bloc," which may be, or become, antagonistic or hostile to other nations or other groups of nations.

2. That the Common Market treaties deal mostly with economic problems.

This is not the place to discuss the political implications contained in the first set of objections. But it should be recalled that, having come together to react against the abuse of economic barriers, they have no intention of erecting a Chinese wall around themselves. They have entered into negotiations with Great Britain, which, at the start, was not particularly warm for the project. In fact, Britain already participates in Euratom, which amounts to a pooling of resources and efforts for atomic research—that is essentially a cultural project; it is associated with the Continental nations in the agreements concerning iron and steel. And many of us hope, and trust, that—pretty soon—Great Britain will have become a full partner. It is in a way symbolical that the first formal association should have been made with Greece, the descendant of ancient Greece and a modern nation with wide trade interests. Approaches have been made by three of the four Scandinavian countries, including Finland; by Austria, which is under a special international status; and by Spain. A link has already been established with a number of the new African republics; negotiations are being conducted with eighteen of them; when an agreement is reached—probably very soon—their cultural as well as their economic growth will be helped. It is permissible to think that if—or when—Great Britain has joined, many of the nations of the Commonwealth will find it to their advantage to join too.

Of course, the first pact signed by the six nations, that which concerned the iron and steel industries, is an economic pact. And so are many of the other pacts, such as the most recent on agriculture. But even these entail study and research in common. We have already noted that one of the agencies, Euratom, was a research agency. If, as has often been suggested, a closer political link binds the nations of the Common Market, more exchanges of all sorts will follow, including, indeed, cultural exchanges. The cultural unity of past ages will be revived.

A tremendous step has been taken already in the last twelve years. Nothing of what has happened would have been possible if a reconciliation had not taken place between nations which during the last century had been engaged in costly and bloody wars. This reconciliation goes further than is generally realized, and it is already affecting the field of learning and culture. Bilateral cultural treaties, concerning mostly the exchange of students, teachers, and scholars, the exhibition of famous works of art of one country in another country, and

the visits of orchestras and theatrical companies, have been concluded by all of the six nations with excellent and very important results. There seems to be no need of a multilateral treaty. Exchanges of all sorts, meetings of teachers, conferences of learned societies, and colloquia have become extremely frequent. If I may speak of my own experience, I have had a large number of German and Luxembourgian students ever since I took my present post at the Sorbonne in December, 1946. Several years ago a group of twenty of my colleagues were invited together to deliver lectures or offer short courses at the University of Munich, and a corresponding number of our colleagues from the great Bavarian university were the guests of the University of Paris in the following year. In the last three or four years the *recteurs* (presidents) of all the universities of West Germany and France have been in the habit of meeting regularly each year.

We know that this is part of a general development of exchanges which is taking place—for the good of all—throughout the world. But it is indeed significant that those very nations which in the past have contributed so much to shape the civilization and the culture of Europe which has since spread all over the world should again be so closely—one is tempted to say so intimately—linked with an earnest, ardent hope of furthering their long-cherished ideal.

VLADIMIR PRELOG

The Concept of Steric Strain in Organic Chemistry

ONE OF THE DIFFICULT QUESTIONS that every scientist must often ask himself concerns the value of his own and of his colleagues' work. In this respect, it is sometimes interesting to listen to the conflicting opinions that the participants at a congress or symposium express among themselves. Thus not long ago I heard after a brilliant lecture of a very well-known organic chemist, on the one hand, that the work described was one of the major achievements of chemistry, one which could scarcely be surpassed; on the other hand, that the work possessed no scientific value whatsoever and that mankind had thereby not advanced a single step. Disregarding purely subjective factors, one comes to the conclusion that these two critics must have been applying quite different criteria for their evaluations, and this leads us to ask which one is right. One can, of course, also ask whether there is any sense at all in occupying one's self with such value judgments. The fact is, however, that life often compels us to judge the value of a scientific contribution. The younger of us have to do it when we choose a field of research or when we join a research team: the seniors have to do it when they decide in which direction they want to lead their co-workers or when they propose one of their colleagues for promotion or for a prize. I have certainly on several occasions been faced with the problem of judging the scientific value of some research or other, and I should like to give you the conclusions to which I have come.

In my opinion, there often exists a confusion between scientific and technological achievement. In a recent issue of *Daedalus* (Spring, 1962, p. 281), Aldous Huxley has formulated the difference between

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science and technology in a very clear way, and I should like to quote his words:

> Science is the reduction of the bewildering diversity of unique events to manageable uniformity within one of a number of symbol systems, and technology is the art of using these symbol systems so as to control and organize unique events. Scientific observation is always a viewing of things through the refraction medium of a symbol system and technological praxis is always the handling of things in ways that some symbol system has dictated. Education in science and technology is essentially education on the symbolic level.

According to this formulation, a scientific achievement is anything which contributes to the development and improvement of a symbol system that is needed or applied in the solution of problems in some branch of science, anything which helps to establish the scope and limitations of such a symbol system. Thus, science itself provides the criterion for assessing the value of a scientific achievement, whereas a technological achievement must be judged mainly from the criterion of usefulness.

One consequence of not distinguishing between scientific and technological achievement is that the latter may be regarded even by scientists themselves as a contribution to science and as such often becomes overestimated. Mankind is not grateful to scientists for their scientific advances but for the benefit (or harm!) that can be obtained through them. A glance at the lists of prize winners and books about famous scientists easily convinces one of the correctness of this assertion. On the other hand, the value of purely scientific advances tends to be underestimated, even by those who make them, and only gradually recognized in the course of time.

I should now like to illustrate these rather general remarks by considering the concept of steric strain, in the development and transformations of which I have, to some extent, been personally involved. It seems difficult to understand how even today textbooks and monographs on theoretical organic chemistry are being written in which this concept does not appear, or is mentioned only marginally, or treated in a quite incorrect manner. For this is a concept which permeates nearly the whole of organic chemistry.

Chemistry looks at its field of activity in terms of two symbol systems, that of structure and that of energy. The concept of the chemical bond, which contains structural and energetic components, is common to both systems. The practical independence of bonds and the approximate additivity of those properties which can be associated with bonds make it possible to reduce the stupifying multiplicity of organic chemistry to manageable terms. The differentiation and ex-

ploration of the types of bonds in various chemical particles—molecules, ions, radicals, transition states—represent two of the most important objectives of chemistry. In differentiating the types of bonds, chemistry encountered a familiar problem: the greater the multiplicity, the more one can explain and the less one can predict. It was therefore an important advance to introduce the steric factor, the strain, in addition to the bond type.

This occurred at an early stage (1885) through the great German chemist Adolf von Baeyer. In an appendix to an experimental paper on polyacetylene compounds (*Chemische Berichte*, XVIII, 2278), von Baeyer added to the well-known postulates of structural theory and stereochemistry the following:

> Die vier Valenzen des Kohlenstoffatoms wirken in den Richtungen, welche den Mittelpunkt der Kugel mit den Tetraederecken verbinden und welche miteinander einen Winkel von 109° 28′ machen. Die Richtung der Anziehung kann eine Ablenkung erfahren, die jedoch eine mit der Grösse der letzteren wachsende Spannung zur Folge hat.

One can thus derive the energy from the structure in that those structures in which the valency angles deviate from their optimal values, like springs under tension, possess higher energy than analogous unstrained structures with optimal valence angles.

It would hardly be appropriate at this stage to criticize the slightness of the experimental evidence upon which von Baeyer's postulate was grounded. Von Baeyer himself commented in his paper (p. 2281): "Zum Schlusse möchte ich noch einmal hervorheben, dass ich diesen theoretischen Betrachtungen durchaus nicht den Werth einer abgeschlossenen und durch die Erfahrung bestätigten Theorie beilege." The basic idea, however, has proved itself correct, and today that part of the strain energy which is associated with deviation of valency angles from their optimal values is known as Baeyer strain.

It is quite instructive to remember that von Baeyer misapplied his own strain theory by assuming, for no very convincing reason, that all rings have a planar structure. From this wrong structural assumption together with the right strain postulate he inferred that many-membered rings are strained and therefore unstable, which seemed to correspond with experience at that time. The great authority of von Baeyer certainly interfered with the development of the chemistry of the many-membered rings for many years. My illustrious predecessor in Zurich, Leopold Ruzicka, who discovered that large rings occur in nature, has often told me how difficult it was for him in the early twenties to overcome the mental resistance against the large rings that had been created by von Baeyer. William Küster's essentially correct

formula for the porphyrins, containing a sixteen-membered ring, was rejected by Ruzicka's illustrious predecessor, Richard M. Willstätter, on the ground: "So etwas kann die Natur dem alten Baeyer nicht antun. . . ." Another example of the great hindering effect of von Baeyer's authority was that Bruno H. Sachse's ideas about the spatial arrangement of the atoms in cyclohexane (1892) were not accepted by his contemporaries; these ideas were forgotten and had to be rediscovered by Ernst W. M. Mohr (1918) before they were generally approved.

This is perhaps the place to sing praise to the chemistry of natural products, a field which has made far-reaching contributions to the development of general theoretical ideas on organic chemistry. It was a natural-products chemist, Ruzicka, who, on the basis of his work in the field of musk odors, steered the Baeyer strain theory onto the right track. When a prominent theoretical organic chemist once asked me if I really thought anything important could come out of work in the field of natural products, I had to remind him that borneol, a substance to which he owed much of his success, is a natural product.

Just as the musk odors led the way to the chemistry of many-membered rings, another much more extensive branch of natural-product chemistry, that of the terpenes and steroids, made significant contributions to the further development of the concept of steric strain. When I came to Zurich in the early forties, at a time when the study of the higher terpenes and steroids was in full swing, I was amazed to see how little attention was paid there to the Robinson-Ingold electronic theories of chemical reactions. The reason for this soon became clear. These theories did not seem to apply in this branch of chemistry; they simply did not account for the dramatic differences in the reactivities of terpenes and steroids. It was obvious that to do this, the steric factor had to be considered in a more sophisticated manner than the current, rather vague notions about steric hindrance would permit.

The subsequent development is familiar to the present-day organic chemists because it is still going on. Help came from the side of physical chemistry. Many facts began not only to indicate that free rotation about single bonds, as postulated by Jacobus H. van't Hoff, was often limited, but also provided information about the relative stabilities of the different forms that arise from such rotations. It was recognized that the energy of a particle depends on the dihedral angles between groups of atoms. The relationships involved are often conveniently expressed in terms of torsion angles about bond and in analogy to classical or Baeyer strain, the energy increase associated with

deviations of the torsion angles from their optimal values is described as nonclassical strain.

The fact that I am talking here about the development of the concept of steric strain is not unconnected with the circumstance that the president who has just been inaugurated by Rice University on the occasion of its semicentennial celebration has made great contributions to the recognition of this new type of strain. In 1947 W. von E. Doering and Milton Farber wrote in a footnote to a paper: "The driving force is plausibly derived from the relief of Pitzer strain," and since then it has become customary to refer to this component of steric strain as Pitzer strain. This name was introduced without asking Pitzer's permission, and I have the impression that he was for some time quite unaware that he had become a colleague of Geheimrat von Baeyer. At any rate, I have been told the following possibly apocryphal story. While I was giving a lecture on the subject of medium rings at the Diamond Jubilee Meeting of the American Chemical Society in 1951, a considerable number of excellent chemists preferred to remain in the corridor outside the lecture room and discuss the smog that lay heavy over New York City that day. Then someone rushed out of the lecture room and called to your president: "Ken, you should be in here. Some guy is talking about something he calls Pitzer strain. . . ."

But Pitzer strain and Baeyer strain do not encompass the total strain. From many investigations dealing mainly with intermolecular attractive and repulsive interactions, it became evident that such interactions must also apply intramolecularly between nonbonded atoms within a molecule. When the structure of a chemical particle is associated with too small interatomic distances, these repulsive nonbonded interactions are effective in raising the energy of the particle. The energy arising from deviations of the positions of nonbonded atoms from optimal interatomic distance and angle can be regarded as the third component of the strain. This kind of strain is especially important in certain types of cyclic structures and was recognized there at a relatively early date (1930) by M. Stoll, who assumed it to be the cause of the special behavior of many-membered ring compounds. Since in cyclic compounds it often arises between atoms on opposite sides of a ring, it is also described as transannular strain.

My account of the historical development of the concept of strain would be incomplete if I did not mention a pioneer in this field, H. C. Brown, the originator of FBI-strains. Even if one cannot agree with his nomenclature for the strains, which is related neither to the Federal Bureau of Investigation nor to the physical reasons for the strains but to the course of their appearance and disappearance during reac-

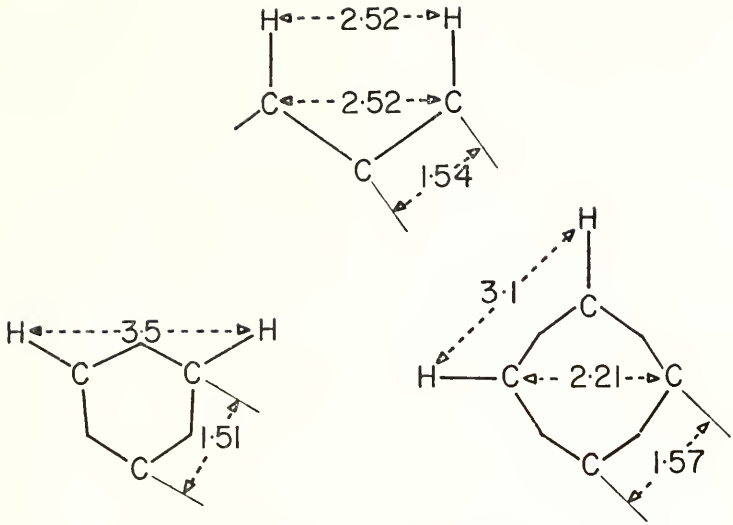
tions, one must acknowledge the importance of his work. Since 1946 he has carried out a long series of systematic investigations on the influence of strain on chemical reactions and has made important contributions to the subject.

The significance of the strain concept lies in the generalization that homologues, isomers, stereoisomers, and conformers with no or only minor differences in the bond types sometimes display striking differences in their physical and chemical properties. In such cases, an analysis of the strain often shows that this is responsible for the observed differences. In other words, the mysterious steric factor can often be traced back to differences in the steric strain which can be understood in a perfectly rational way. To illustrate this assertion, I now want to mention a few examples. These will be drawn mainly from the experiences of my colleagues in Zurich and myself, which will perhaps emphasize that even a small research community cannot get on without the concept of steric strain.

1. It is rare that the steric strain in an organic compound is of such dimensions as to have a measurable influence on the interatomic distances in σ-bonds. Either it completely prevents the existence of such bonds as in many bridged polycyclic systems or else other parameters of the structure, such as bond angles and torsion angles, become altered in an energetically unfavorable sense. The four-ring compounds like cyclobutane are exceptional in this respect. In cyclobutane the C–C bonds are found to be longer than normal, whereas in cyclopropane the bonds are shorter than normal (Fig. 1). The latter result may have something to do with so-called "bent bonds," but if so, the same effect should apply, somewhat mitigated, in the four-ring. Both molecules contain Baeyer strain arising from the large deviation of the C–C–C-bond angles from optimal, and also Pitzer strain arising from the eclipsed relationship of the ring members. But cyclobutane contains in addition very strong repulsive 1,3 C,C-interactions and it is these that, according to J. D. Dunitz and Verner Schomaker, are mainly responsible for the increase in length of the C–C bonds.

2. In contrast to this, there are many examples where strain either prevents or counteracts the formation of a π-bond. The transconfiguration of the double bond does not seem to occur in rings with less than eight members, and it is strained in the eight-, nine-, and ten-membered rings, as has been shown from purely chemical evidence and also, rather strikingly, from the thermochemical investigations of Richard B. Turner and William R. Meador (Fig. 2).

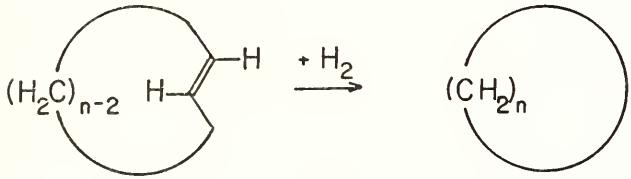
3. It has been known for a long time and summarized in the so-called Bredt's rule that a bridged bicyclic system cannot possess a double bond at the bridge head, at least for classical rings with three



STRAIN vs. σ-BOND

Fig. 1

(I) trans-CYCLOALKENE (II) CYCLOALKANE



n	ΔH_{I-II}	S_{II}
6	not known	0
7	not known	6
8	32	9·5
9	26·5	12
10	24	12

kcal·mole^{-1}

STRAIN vs. π-BOND

Fig. 2

to seven members. In the course of our investigations on many-membered rings, we were able to show that in accordance with expectation Bredt's rule does not apply to systems which contain many-membered rings, as may be seen from the example in Figure 3.

4. Many examples are known in which strain counteracts the conjugation of double bonds by preventing the coplanarity that is necessary for delocalization of the electrons. This kind of effect is generally easy to recognize because it has a great influence on the electronic spectrum. In this connection I should like to mention some results of

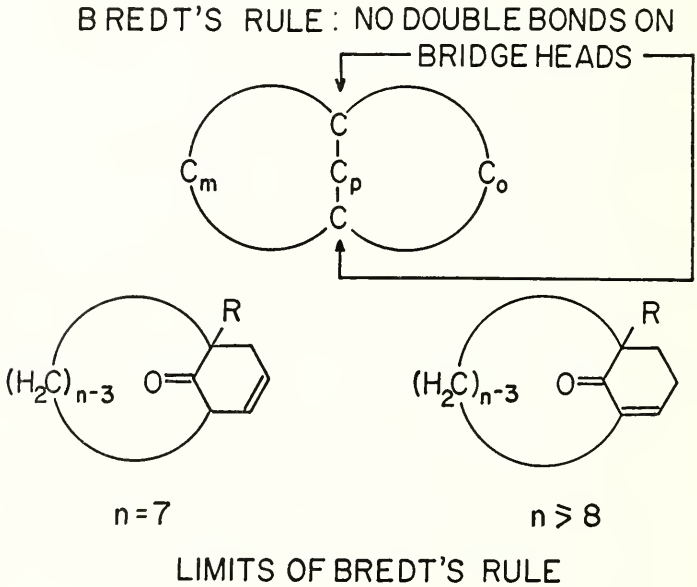
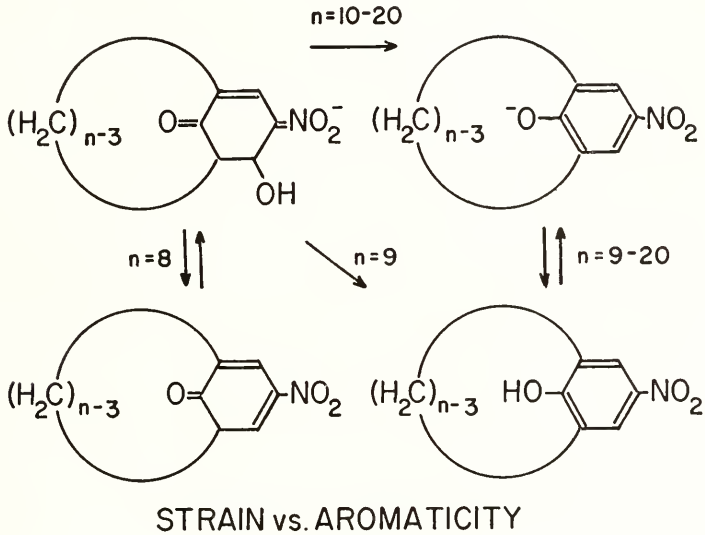


Fig. 3

my own group on *m*-bridged *p*-nitrophenols represented in Figure 4. As the polymethylene bridge is made shorter, the extinction coefficients and the positions of the absorption bands are affected. In the case of the eight-membered ring the resulting strain even cancels the aromaticity of the nitrophenol and the nitrophenolates itself (Fig. 5). Albert Eschenmoser and Edgar Heilbronner have made similar observations with 2,7-bridged tropones.

5. One of the largest and most important fields for the application of the strain concept to chemical problems is that of conformational analysis. For molecules whose structure permits rotation about single bonds and hence alteration in the spatial arrangement of the atoms, the relative stabilities of the various possible forms or so-called conformations is largely determined by steric strain. Conformational analysis is thus more or less equivalent to strain analysis.

The spatial arrangement of the n atoms that constitute a molecule is determined by specification of $3n - 6$ independent parameters. For chemical purposes, it is often convenient to describe the form of a molecule in terms of such parameters as bond distances d, bond angles ϑ, and torsion angles τ, even though (in cyclic systems, for example) these may not all be independent of one another. The strain of the molecule S (Fig. 6) is then taken as the sum of all Baeyer strains, Pitzer strains, and nonbonded interactions. The Baeyer strain is a function only of the bond angles ϑ, the Pitzer strain a function mainly of torsion angles τ, and the nonbonded interactions a function of



STRAIN vs. AROMATICITY

Fig. 4

all three kinds of parameters. In strain analysis of a stable particle the bond distances can be assumed to be constants so that only the variation of the bond angles and torsion angles need be taken into account. If the variation in direction of the nonbonded interactions is ignored, as is probably justifiable for a first approximation, these interactions depend only on the interatomic distances r.

It would thus seem as if all the factors required for a quantitative, general treatment of strain analysis were available and that the problem could be reduced to a merely computational one. Formidable as this might be in the case of a complex molecule, it could certainly be handled with modern electronic computers, provided that the functions relating the various strain components with d, ϑ, and τ were known. Unfortunately, we do not know these. At most, we know the extreme values, but the functions themselves are not known with the

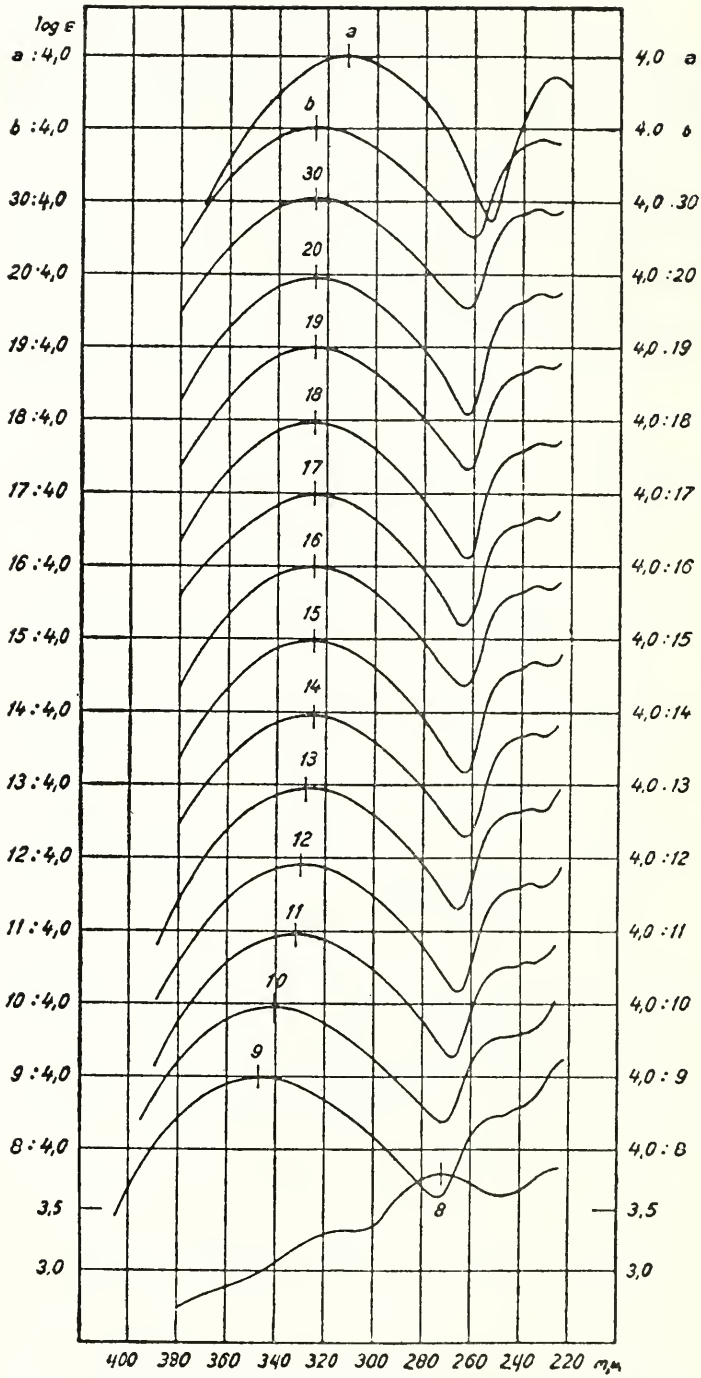


Fig. 5.—Absorption spectra of bicyclic *p*-nitrophenols. See Fig. 4

required degree of accuracy. The rather arbitrary functions that have been used up to now for such calculations are so inexact that the computational effort required in complicated cases—the ones that are really interesting—is scarcely justified, and the results of such calculations may be taken with a high degree of skepticism.

Although a general, quantitative analysis of strain is at the moment out of the question, it is possible to make use of empirical data for comparison of the strain of conformations which do not differ too much. The results obtained by such qualitative or semiquantitative strain analyses in the last few years have been of great importance to

TOTAL STRAIN $S = S_B + S_P + S_N$

BAEYER STRAIN $S_B = \Sigma f_1(\vartheta_i)$

ϑ_i = valence angles

PITZER STRAIN $S_P = \Sigma f_2(\tau_j)$

τ_j = torsion angles

NON-BONDED INTERACTIONS

$$S_N = \Sigma f_3(\vartheta_i, \tau_j) = \Sigma f_4(r_n)$$

r_n = interatomic distances

Fig. 6

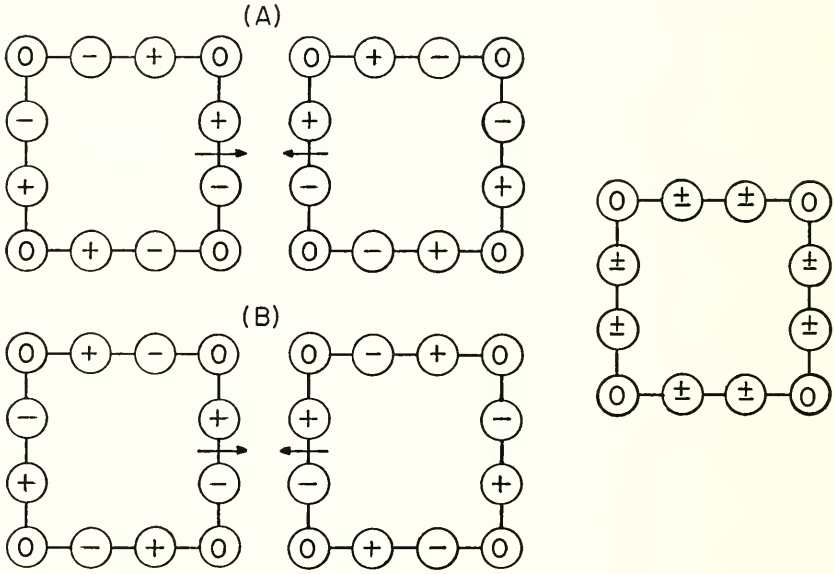
the understanding of the steric factor in almost all branches of organic chemistry.

It is hardly possible within the scope of this lecture even to sketch the general outlines of conformational analysis which extends from ethane via terpenes, steroids, alkaloids, antibiotics, and synthetic high polymers to the proteins and nucleic acids. I should therefore again like to restrict myself to one example from our laboratory in Zurich.

During the last few years, Dunitz and his colleagues have investigated the conformations of the medium ring compounds with eight, nine, ten, and twelve members by X-ray analysis. This work has shown that each size of ring is associated with one, more or less invariant, characteristic conformation that must depend on the particular balance between the strain components in each case.

In most cases the X-ray results have been quite clear-cut, but in the

case of cyclododecane it turned out that two different conformations were equally compatible with the diffraction data. The crystals are disordered, and the average structure, which is all that can be obtained by X-ray analysis, corresponds to the superposition at each lattice-point of two molecules, each of half-weight, related by a mirror-plane. From Figure 7 it is evident that there are two quite distinct conformations which, by mirroring, yield exactly the same superposition pattern. At this stage strain analysis was called in. One conformation (*A*) is associated with a Pitzer strain of some 20 kcal/mole^{-1},



STRAIN vs. CONFORMATION

Fig. 7

whereas the other (*B*) seems practically free from any kind of strain. The possibility *B* is evidently the correct conformation, and one may add here that, according to thermochemical measurements, cyclododecane is indeed virtually free from strain. Conformation *B* was later found to occur again in crystals of azacyclododecane hydrobromide.

I hope that I have been able to convince you through these few examples that the strain concept is one of the fundamental concepts of organic chemistry and that anyone who has made important contributions to its understanding and development—such as the new president of Rice University—has performed a very valuable service to science.

SIR GEOFFREY INGRAM TAYLOR

Scientific Diversions

When an old man is asked to give an address, he is likely to assume that his audience is willing to listen to his recollections of the past. On the occasion of the fiftieth anniversary of the founding of the Rice Institute, I can perhaps plausibly make that assumption because my own period of scientific activity has coincided very nearly with that of Rice's existence. If a present-day scientist were to read a paper written fifty years ago thinking it was a more recent publication, he would probably think of the author as an amateur playing at being a scientist without the necessary training. Up until comparatively recent times a man who started scientific work equipped with brains but little training had a reasonable chance of finding out something new, but the recent great increase in the number of highly trained young scientists looking for something to do makes the lot of the amateur much less attractive than it was fifty years ago. Even so, it seems to me that there are still things in physical science that people who have enthusiasm but not a great deal of training can do, using quite simple mental or material tools, and I take this opportunity to talk about this aspect of science because it is one to which my own limitations as well as my inclination have turned my attention. I had to give a title to this address before I had written it and I first thought that I would use the words "amateur scientists," but on looking up the meaning of amateur I found that it is used to describe work which is not up to professional standards. Since that was not quite my meaning, I changed it to indicate the course which a scientist who works with the simplest tools and ideas is likely to take.

My own experience is that if I start on something that turns out to be worth doing, the difficulties in pursuing the subject directly have a

SIR GEOFFREY INGRAM TAYLOR is a fellow of Trinity College, Cambridge University. An applied mathematician, he was one of the scientists who worked on the original atomic bomb project (the Manhattan District). This lecture was delivered in the Grand Hall, Rice Memorial Center, at 9:00 A.M., October 12, 1962.

habit of increasing until the effort involved in dealing with its increasing complexity becomes too great for me. At that stage it sometimes happens, if I am lucky, that a younger man trained in the use of more sophisticated mental or material equipment may take the lead. On the other hand, the pursuit, even in the early stages, of a new line of inquiry often raises one to a position from which one can see interesting sidelines opening up which were not visible, so to speak, at ground level. In such cases I tend to be diverted into what may be an easier path. It is this kind of diversion I have in mind in the title of this address rather than a pleasurable pastime. I think that my own case is merely one example of a well-known fact that a man who starts some new line of work is often not the best, and may even be the worst, person to carry it on.

From the time of Franklin onward this country has been rich in scientifically untrained amateurs who have made contributions to science with simple apparatus and ideas. You probably know as much about their histories as I. I thought that a few remarks about my own experience with simple apparatus and that of some English amateurs might not be out of place on this occasion.

I would like first to mention my own grandfather, George Boole, because he was a man of genius whose career would have been quite different if he had been born within the last fifty years when education has become available to anyone who can really use it. George was born in 1815, the son of John Boole, a poor cobbler who had a small shop in Lincoln. He had no formal education beyond what he picked up at a small elementary school, but his father, John Boole, was interested in science and spent much time in making a telescope and other philosophical instruments to the detriment of his business. George was devoted to his father who inspired him with an interest in natural philosophy—we now call it physical science—but there were no facilities in Lincoln in the 1820's and 1830's for scientific education, and Boole's real education derived entirely from reading books lent him by a friendly bookseller. In this hard way he taught himself Latin, Greek, Hebrew, German, French, and Italian. Then when he was seventeen and was teaching at a small elementary school he began to borrow books on mathematics and so found his real calling. In a few years he began corresponding with some mathematicians in Cambridge who then wanted him to go there and be trained at the university. Boole, however, did not accept their invitation because his father had run into financial difficulties, and he was helping to maintain the family home.

Though Boole was still a poor schoolmaster in 1842, he must have been highly regarded by his scientific contemporaries as I learned one

hundred and eighteen years later in the following way. When I was a small schoolboy I was given a ticket for the Christmas lectures for children at the Royal Institution in London. These lectures, though addressed to children, were sometimes attended by adult members of the Institution, and at one of them I was introduced to Lord Kelvin as a grandson of George Boole. I have a faint memory of a kindly and bearded old gentleman looking down at me and saying that Boole had been one of the people from whom he had asked a recommendation when he applied for his professorship at Glasgow in 1842. I had always suspected that I must have got confused or misheard Kelvin because Boole has always been known as a very pure mathematician, the principal founder of symbolic methods in mathematics and logic and of Boolean algebra, and one would not expect the young Mr. William Thomson, as Kelvin then was, to ask for a recommendation for the professorship of natural philosophy from such a character, particularly when he was only a young schoolmaster in a small elementary school. However, three years ago I had to say something about Kelvin at a meeting of the Institution of Civil Engineers in London, and I thought it just worthwhile to search Sylvanus P. Thompson's *Life of Lord Kelvin* for a possible reference to his sponsors in his application for the Glasgow professorship. Sure enough, the recommendation of G. Boole, Esquire, was quoted, and I was particularly interested to learn that the paper of Kelvin, which Boole picked out as having interested him, was one on hydrodynamics, a subject which has always fascinated me. In 1847 Boole was called to the professorship of mathematics at Cork in Ireland, though he had no education after leaving his elementary school and still less a university degree.

My grandfather was an amateur who turned professional. His third daughter, Alice, was the purest example I know of an uncompromising scientific amateur. She was born in 1860 and was only four when her father died. She had the kind of education that was supposed to satisfy ladies in those days, some classical literature, no science except the first two books of Euclid, but otherwise the arts then expected of a lady. Then her eldest sister married Howard Hinton, a teacher of mathematics though not a very effective original mathematician. He was an imaginative kind of man, and he began to think about four-dimensional geometry much on the same kind of lines that inspired Edwin A. Abbott to produce the romance *Flatland*. Hinton's ideas inspired his young sister-in-law Alice to think about four dimensions, but, though the only technique she had for this purpose was her knowledge of Euclid, she obviously had the root of the matter in her. In a few years during the 1880's of the last century, she succeeded in rediscovering the six regular figures or polytopes which can exist in

four dimensions and produced complete sets of sections of them as they would appear in passing through our three-dimensional space.

It would take too long for me to explain how, using nothing but ruler and compass, she was able to do this and construct cardboard models of the sections, but I can perhaps indicate her method. A section of a regular polytope is a three-dimensional figure bounded by polygons which are sections of the regular solids that bound it. If we could see in a material form the successive sections of a polytope as it passed through our three-dimensional space, they would first appear as a point, a line, a regular polygon, or one of the regular solids, depending on its orientation to our space. The three-dimensional section would grow, and then diminish and disappear, just as, say, a cube when passing through a plane (that is, a two-dimensional space) might appear first an equilateral triangle increasing in size from a point. The triangles would develop into semiregular hexagons. These in turn would become regular as the center of the cube reached the plane, and the sections would then repeat themselves in the reverse order till the last vertex crossed the plane, when the section would disappear. An inhabitant of Flatland who constructed sections of a cube in Alice Boole's manner would find, by counting the number of separate edges as they appeared and disappeared in his construction, that a cube has eight corners, six faces, and twelve edges.

The most complicated of the six regular four-dimensional figures is bounded by 600 tetrahedra, 20 meeting at each of its 120 vertices. Plate I, *a*, shows a tetrahedron seen looking at a vertex along a line perpendicular to the face which is invisible if the tetrahedron is opaque. Various possible plane sections are shown; they are all either triangles or quadrilaterals. Plate I, *b*, shows the way Alice Boole constructed part of her model of one of the sections of the 600-cell polytope. She found the shape of each face by Euclidean construction executed on cardboard. These faces are all triangles or quadrilaterals. Then she cut the card half through so that it could be folded on edge lines. The part which was not required was cut away completely, and, if no mistake had been made, the figure constructed by folding so that all separated edges met must close up. Alice Boole made sets of sections of all the six regular four-dimensional figures during the 1880's of the last century. She regarded this work as her private amusement, just as other ladies would take up embroidery or paint water colors of the Italian lakes, and the idea that it should be published never presented itself to her. When she married, her duty to her home and children took precedence over her hobby, and she dropped it completely.

Some years later, however, Professor Pieter H. Schoute of Gro-

ningen in Holland, using entirely analytical methods, published two-dimensional projections of the three-dimensional center sections of the regular four-dimensional figures which he had calculated. A friend of Alice Stott, as Alice Boole was named after her marriage, saw Schoute's papers and called her attention to the fact that they were pictures of shapes identical with her models. She then set up her models, photographed them, and sent prints to Schoute, who was as unable to understand how she had obtained noncentral sections as she was to understand his analysis. In Plate II are shown two figures from Schoute's paper on the 600-cell polytope and one of the original photographs sent by Alice Stott to Schoute. You will notice the correspondence, though Schoute's central section was not in exactly the same orientation to our space as Mrs. Stott's. The left-hand upper figure is almost identical with the third model from the right of the top row of Mrs. Stott's photograph. Mrs. Stott's second model from the right has a zone of faces round a small triangle which is similar to a zone in Schoute's figure shown on the upper right. Schoute persuaded Mrs. Stott to publish her method, and they co-operated fruitfully during the rest of his lifetime.

The history of mathematics is full of people who might be described as amateurs, because, though they had had little or no training in the subject while students, they retained an interest in it and extended their knowledge when employed later in unrelated occupations. A very remarkable example is that of the Indian mathematician Srinivasa Ramanujan. He had no university training, but his amazing insight into the properties of numbers and algebraic series was well known among his school friends and masters at an early age. On leaving school, he failed in the university entrance examination in 1906, owing to his lack of knowledge of subjects other than mathematics. He then spent a few years filling some notebooks with a large collection of theorems and formulas which came entirely out of his head. When some years later they were examined by Professor G. H. Hardy, it was found that some were solutions of problems which had defeated the best professional mathematicians for years, some were theorems that had already been stated but were unknown to Ramanujan, some were wrong and had errors which could not have been made by anyone who even had an elementary mathematical training.

In 1909 Ramanujan, having married, had to get a job, and became a poorly paid clerk in the Madras Port Trust. In 1912 his work was seen by G. T. Walker, who was a good mathematician and immediately recognized its quality. Walker persuaded the government to give Ramanujan a research studentship. In 1914 he came to Cambridge to work with Hardy and to be taught mathematics. He continued to

produce a tremendous spate of results, often without giving proofs, and mathematicians have been kept busy proving them ever since. Ramanujan had a great facility for remembering and understanding peculiar properties of numbers; indeed, Professor John E. Littlewood said of him, "Every positive integer was one of his personal friends." Hardy told us once that when Ramanujan was ill in the hospital he visited him there and, trying to think of something which might interest this very sick man, remarked that he came in a taxi whose number was 1729, remarking that this seems a rather dull number, being $7 \times 19 \times 13$. "Not at all," said Ramanujan immediately. "It is the smallest number expressible as the sum of two cubes in two ways [$9^3 + 10^3$ or $1^3 + 12^3$]."

Like Boole, Ramanujan was an amateur who became a professional. Whether he would have been a better professional if he had had an early training in mathematics is a debatable question. On this point I cannot do better than quote from Hardy's obituary notice of Ramanujan, who died at the age of thirty-three.

> Opinions may differ as to the importance of Ramanujan's work, the kind of standard by which it should be judged, and the influence it is likely to have on the mathematics of the future. It has not the simplicity and the inevitableness of the very greatest work; it would be greater if it were less strange. One gift it has which no one can deny, profound and invincible originality. He would probably have been a greater mathematician if he had been caught and tamed a little in his youth; he would have discovered more that is new, and that no doubt of greater importance. On the other hand he would have been less of a Ramanujan and more of a European professor, and the loss might have been greater than the gain.

Now I would like to describe quite a different kind of amateur scientist. In several branches of science, observations at places spread over the country have been needed, and professional scientists have organized groups of enthusiastic amateurs who can sometimes give valuable service without much training. One such case is that of meteorology. It had long been the practice, in England at any rate, for amateur meteorologists to report observations to a government-supported meteorological organization. About the end of the nineteenth century people began to realize that to limit observations to ground level is unnecessarily restricting, and the first people to start upper-air observations, in England at any rate, were mostly amateurs. The best known of these was Mr. W. H. Dines. Dines had a small private income which he supplemented at times by teaching. After a disaster in which a bridge was blown down, a Wind Force Committee was set up to advise constructional engineers, and Dines became a member.

He began exploring wind structure with kites which he made himself. He also designed and made in his workshop recording instruments to put in them and a winch to wind in the kite wire. In the minutes of the Wind Force Committee for December, 1887, it is recorded that "Mr. Dines be authorised to hire a steam engine if available at a cost of £6." This gives the scale of the help which an amateur scientist could expect in those days.

However, Dines persisted, making and using kites which carried his instruments up to 10,000 feet. This limitation to heights less than 10,000 feet could only be surmounted in those days by using free balloons, and the records could only be recovered in a small proportion of the ascents. The expense of equipping many balloons big enough to carry the then existing recording apparatus was too great for Dines. He therefore designed in his workshop an instrument which recorded temperature against pressure. The record was made by a steel point on a polished slip of metal about as big as a postage stamp, the barometer being attached to the point and the thermometer to the slip. In these days, when such an immense amount of effort is devoted to miniaturization, it is worth recording that the whole of Dines's balloon meteorograph including thermometer and barometer weighed just 1 ounce and could be carried, with its radiation screen and a cage to keep it off the ground when it returned to earth, by a large-sized child's toy balloon. Ultimately, when the value of his work was universally recognized, Dines was given an honorarium of £200 a year and the services of a mechanic to enable him to carry on with it.

Another amateur, Mr. C. J. P. Cave, also did good service to meteorology by flying kites. Unlike Dines, Cave was by English standards a very rich man who owned one of the most beautiful parks in the south of England. I remember the first time I visited him. I was being driven from the local railway station by his chauffeur. We went through his lodge gates, and I reached for my suitcase. "You won't need that yet," said the chauffeur. "Mr. Cave's house is two and a half miles away." You might think that in a park that size kites could be flown without danger to the neighbors, but I was told of one occasion when the kite wire broke near the winch while Cave had a string of kites in the air. The kites came down a little, and a length of the wire dragged along the ground. The drag of the wire was enough to hold the kites in the air, and there was a cross-country chase of fifty miles or so before the broken end of the wire could be caught and held. In those days there were luckily very few overhead cables.

This activity stopped when the First World War started, and, when flying became commoner, official meteorological flights started, and there was no more room for the amateur in that field. Cave, how-

ever, was an ingenious man, and when the professionals took over upper-air research he invented a new diversion. He noticed that in the roofs of the crypts of many English churches and cathedrals there are often beautiful stone carvings which had probably never been seen since they were produced in medieval times. He made himself a portable floodlight arrangement which could be directed vertically and traveled about England recording these carvings. Finally, he produced an interesting book full of his photographs.

I have described how my grandfather developed from an amateur into a professional mathematician and how one of his daughters became and remained an amateur. I might, if the time had been available, have described how in the generation before that of Boole the career of my great-grandfather's brother, Sir George Everest (for whom the mountain was named), was also diverted into the science of geodesy from his occupation as a soldier in the service of the Honourable East India Company. I mention it now as an example of how a love of science often runs through several generations of a family. I, in the fourth generation, have also been infected with the same virus, but, in my case, it may be said to have propelled me in the reverse direction to that of my predecessors, for while my scientific education should have fitted me to keep up with the leaders in the use of more and more sophisticated ideas and apparatus, my inclination has always been toward the simplest possible scientific methods and hardware.

When I had taken my first degree after three years at Cambridge, I asked my professor at the Cavendish Laboratory, J. J. Thomson, whether he could suggest a research project which I might attempt. This was the regular way for students to begin their careers, and I think few of us stopped to think of the amazing fertility of a mind which could produce a whole string of worthwhile ideas for each of a dozen or more students. J. J. produced a number of attractive ideas, and I chose one of them. It was this: If, as had recently been suggested, light consists of spots or quanta of energy localized in space, interference must depend on the phase of a quantum falling on any particular place being somehow related to the phase of another quantum falling later on the same spot. If, then, the intensity of light forming an interference pattern is reduced, the time interval between the incidence of successive quanta on the same spot must increase, and, if the intensity is reduced to an exceedingly low value, the phase of the disturbance produced in a photographic grain by a quantum may not remain unimpaired for a sufficiently long time while waiting for the next quantum to interfere with it. J. J. therefore suggested that I might set up a simple interference pattern and

see whether it ceased to be well defined when the light intensity was reduced.

I chose that project for reasons which, I fear, had nothing to do with its scientific merits and set up in the old children's playroom at my parents' home a vertical needle onto which I shone the light of a gas jet placed behind a vertical slit made by a razor blade in a piece of metal foil stuck to a piece of glass. I set a photographic plate up some six feet away and obtained a good interference pattern. Then I reduced the light by inserting successive sheets of dark glass between gas jet and slit and increased the exposure time. Finally, I got to the stage when I calculated that I would get enough blackening of the plate if I made the exposure six weeks, and I had, I think rather skilfully, arranged that this stage would be reached about the time when I hoped to start a month's cruise in a little sailing yacht I had recently purchased. I have mounted one of the original photographic negatives, made three years before the Rice Institute was founded, as a slide to show what the pattern was like. A portion of a positive print from this negative is shown as Plate III. The final three-month exposure was very faint, but it showed a pattern which was as sharp as the one illustrated.

Though this experiment, performed with homemade apparatus costing perhaps two dollars, was successful in giving a definite negative result which is referred to in books on optics, I did not feel a call to a career in pure physics. When an opening came in geophysics, I followed that diversion and became a meteorologist. The loss of the "Titanic" through striking an iceberg had induced the British Government, with the transatlantic shipping lines, to fit out an expedition to explore and report on the icebergs in the North Atlantic. I was appointed meteorologist and the old-fashioned 230-ton wooden whaling ship "Scotia" was chartered for the expedition which was to start from Dundee early in 1913. I borrowed a kite winch from Mr. C. J. P. Cave, some instruments from the Meteorological Office, and had some kites made to lift the instruments, but on going to Dundee to fit the kite winch I was confronted with a setback, for the captain said that under no circumstances would he go to sea with anyone who proposed to fly a kite from his ship. He had been captain of the "Scotia" during W. S. Bruce's expedition to the Antarctic in 1901. Bruce had tried to get kites into the air by releasing them from a whaleboat downwind from the ship, just in the way boys fly kites, and every attempt ended in failure. The kite immediately dived into the sea, and the time taken in recovering it upset the routine of the ship. I devised a simple method for avoiding this trouble, but had to indulge in a slight prevarication with the captain, telling him that

the winch I was fitting on his quarter-deck was for sounding, without adding that it was for sounding the air rather than the sea. All went well with the preparations, and everyone was aboard at the time we were supposed to sail. We left the dock but had to anchor for twenty-four hours in the river outside until such time as the crew sobered down enough to work the ship. Plate IV is a photograph of the "Scotia" which I took from the ice floe in which she was imbedded. It shows the quarter-deck from which the kites were flown by hoisting them to the top of the mizzenmast, where the air is much less turbulent than it was in the place from which Bruce had tried to get them up.

The principal thing I did on that voyage was to measure the temperature distribution in the first few thousand feet over the sea and use the results to find the heat transfer from sea to air due to turbulence. The interest in turbulence so aroused made me think about other effects of turbulence, and this led me to think about aero- and hydrodynamics in general. The thing that struck me then (in 1913) was the fact that the classical theory of hydrodynamics predicts results which are wildly different from those of experiments. I realized that the reason for this was that classical theory involved the assumption that there is perfect frictionless slipping of fluid at solid surfaces, but the direct approach involved in making a mathematical picture of the actual flow involved such formidable difficulties that I diverted my effort to finding cases of fluid flow where the effect of friction at the boundaries might be expected to be insignificant compared with other predictable phenomena. This led me to experiment with rotating fluids for comparison with predictions, based on classical theory, of effects of rotation on fluid flow. Here the classical theory yielded correct predictions.

I have perhaps said enough to indicate how, when a direct approach to a problem seems too difficult, a cast sideways in search of an easier problem involving some, at any rate, of the elements of the more difficult one may be rewarding and may even give one insight into the main line of research from which one had been scared by its difficulty.

As a last example of how scientific investigations which begin with one objective are liable to end in some apparently quite unrelated field, I will sketch the course of some of my own investigations of the last few years. Nearly ten years ago a young physiologist working at an animal research station asked me whether I could help him to understand how drugs are dispersed when injected into blood vessels. I could make little headway with this problem because the geometrical configuration of the body is so complicated, but, by con-

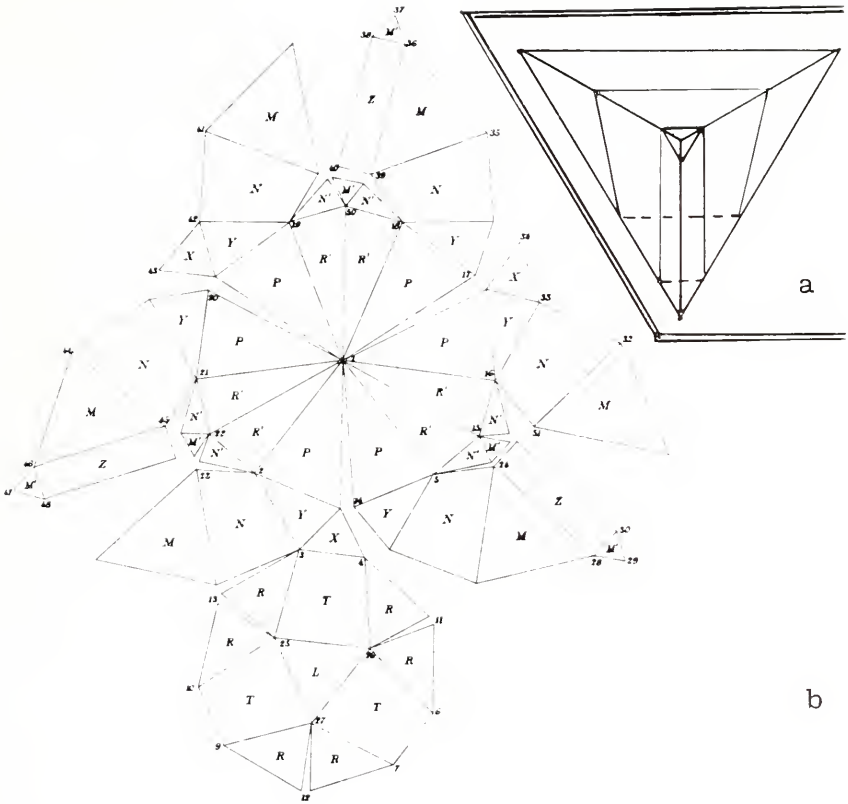
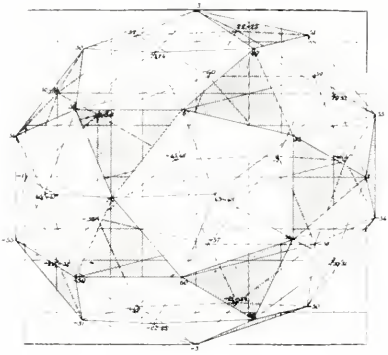
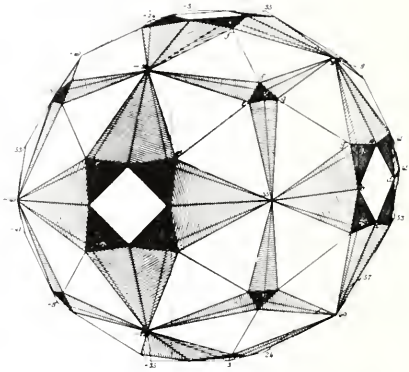


PLATE I





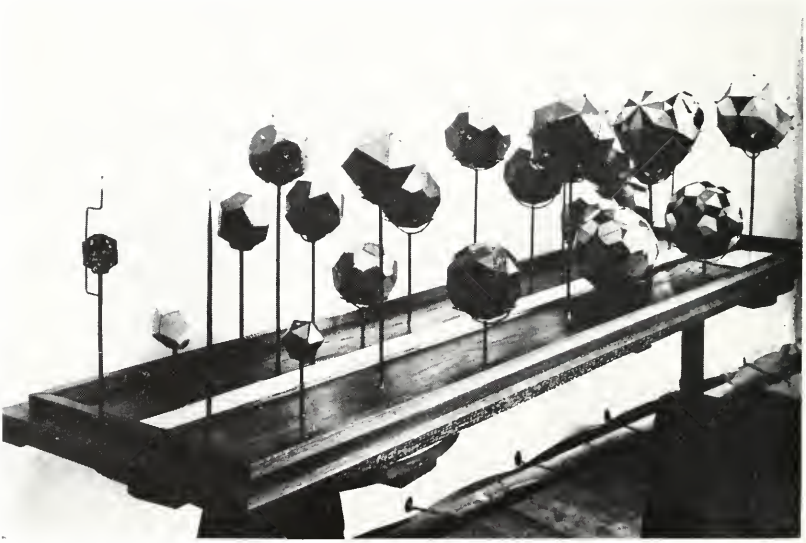


Plate II

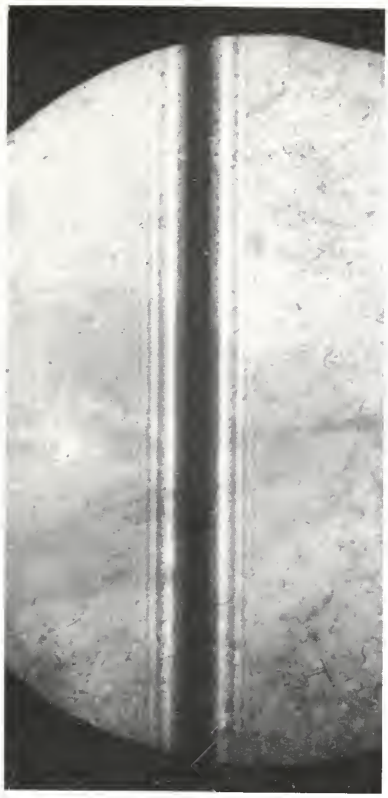


PLATE III

PLATE IV

fining my attention to the dispersion of a contaminant injected into a fluid flowing through a straight capillary tube, I formed a picture of a simple case of dispersion, which, though it did not help the physiologist much, turned out to be of some use to chemical engineers. The dispersion in a capillary tube depended on a balance between the longitudinal convection and molecular diffusion in the radial direction. Since the retarding effect of turbulence in pipes is analogous to that of a much increased viscosity, and the distribution of velocity over the cross-section, which is the course of longitudinal convective dispersion, depends on the turbulence, it was possible to extend the results to give a picture of dispersion in turbulent flow through a pipe, and so it became possible to give a mathematical description of the spread of the mixture zone when one product follows another through a pipeline which may be a thousand miles long.

These studies dealt with the dispersion of one fluid in another with which it can mix. If the fluids cannot mix, quite a different situation arises, and some years ago the Humble Oil Company invited me to Houston and called my attention to experiments which several oil companies were doing on the displacement of oil in porous beds by water and other fluids. Such situations are very complex, involving flow of viscous fluids in narrow passages and a knowledge of the shape of the interface between adjacent fluids flowing through the same bed. Even with the simplest geometry, situations of this kind are very difficult to analyze mathematically, and surprisingly little seems to have been done experimentally. Consider, for instance, what happens if one fills a tube with a viscous liquid and then blows it out by air pressure applied at one end. Some fluid is blown out and some is left behind. It is very difficult to deal with this situation mathematically, but comparatively easy experimentally. I have taken the easier path. One might ask, "What is the interest in making such experiments?" The answer I would give is that it provides a steppingstone by which certain problems of considerable practical interest may be approached. One such problem has worried engineers for many years; namely, what is the physical condition which determines where the oil film in a lubricated bearing cavitates? Those engineers who have worked on this problem have, I think, always assumed that the phenomenon is of the same nature as that which occurs when the pressure above aerated water is reduced. Now it appears that though internal cavitation of that kind does occur, external cavitation analogous to what happens when air blows liquid out of a tube also occurs.

Studies of the ways in which low pressures can be formed in fluids

occupying narrow passages such as the clearance spaces of lubricated bearings have led me to think about cases where similar effects occur in other practical operations, and I have derived much pleasure in devising models sufficiently simple to analyze mathematically and sufficiently realistic to throw some light on the mechanisms actually used. The drainage of water out of the pulp from which paper is made is one such case; the mode of action of paint brushes and of those rollers which people use in painting walls are other examples of the variety of fields into which a series of related ideas have diverted me since I started trying to answer a biologist who asked me his question about how drugs are dispersed when injected into a blood stream. I have not answered his question, but have had an amusing time in following the various bypaths into which it led me.

In this talk I have tried to convey the idea that the pleasure and interest of being a scientist need not be confined to those gifted people who have the ability to pursue the highly specialized studies which are necessary for those who would reach the main frontiers of scientific advance. There is still a place in science for humbler and less sophisticated folk, even though the difficulty of finding it may be greater than it was fifty years ago.

ALLAN NEVINS

The (Happy?) Relations of Public and Private Universities

LATE IN THE NINETEENTH CENTURY William Graham Sumner wrote a famous essay on "What Social Classes Owe to Each Other"; and it is fair to say he decided that, above all else, they owe each other competition—rigorous competition. Nobody has yet written an essay on what public and private universities owe to each other. The whole large subject of their relations has lain untouched save for a brief address by Chancellor Lawrence A. Kimpton of the University of Chicago in 1959: an address in which he expressed, as I think, some very wrongheaded opinions. Anyone undertaking an essay on mutual duties, however, can hardly escape the conclusion that what public and private universities most owe each other is again competition. John Doe best helps Richard Roe, and both best help society, by engaging in a fair but earnest race; Yale and Cornell, Rice and Texas, best help each other in the same way.

It is true that the same general maxim may be stated in gentler terms. Indeed, it was so stated a century ago by John Stuart Mill. Mill laid down the axiom that all education, higher and lower, is best conducted under the competitive sway of three agencies: the state, the church, and private enterprise. In other words, education profits from variety, not uniformity, and competition, not monopoly; the larger the number of responsible agencies concerned in it the better; and government, religion, and private leadership can check, balance, and stimulate each other. Rice University, the University of Texas, and Baylor University precisely meet John Stuart Mill's tripartite prescription.

We have witnessed an explosion of knowledge, an explosion of

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student bodies, an explosion of leisure, and an explosion of world dangers and duties; at any rate, an expansion of all four so massive and sudden that it seems explosive. It is not the sciences alone that have been revolutionized since Einstein, or psychology alone since Freud and Jung, or economics alone since Keynes; every branch of learning has undergone its sea change. The explosion of students is a natural product of the union of democracy with affluence. World responsibilities, against which the isolationists of the twenties fought a rear-guard action, have become so numerous that they impose their demands upon education in exigent terms.

The rigor of the battle for American survival in our harsh new world recently drew from the American Council on Education a statement below which the signatures of Nathan Pusey, of Harvard, and Clark Kerr, of California, and of other university presidents, public and private, stood side by side. The statement began with the sentence: "A great and unique strength of American higher education stems from the historic coexistence of strong private institutions and strong public institutions." It closed with the statement that "the times call for a greater investment in higher education as a whole" and that "universities of both types must join hands in a sustained effort to wring financial support from all . . . sources." I rather like that word "wring."

The relative position of public and private universities in the United States has altered, is altering, and will continue to alter in favor of the public institutions. This fact is now patent and unescapable. They who fail to realize it are simply victims of a failure to comprehend recent developments. They are under the spell of the men who planted Harvard in 1636, William and Mary in 1693, Yale in 1701, and King's College or Columbia in 1754, and so founded a tradition which long dominated the American mind. Throughout the eighteenth century higher education was exclusively in private hands. Until after the Civil War it so remained. We had no real university; but the vigorous seats which bore the name remained, except perhaps in Virginia and Michigan, independent of the state. The primacy of Harvard, Yale, Columbia, and Princeton stood unchallenged until years after 1865; and when the first true university arose in the 1870's at Johns Hopkins, it too was a private institution. Even when Edwin E. Slosson made his choice of twelve great American universities in 1912, all but four were endowed; and, of those four, two, Minnesota and Illinois, were admitted to his list with doubt and reservations.

Down to the end of the First World War the private universities retained their suzerainty over higher education. While the renowned

elder seats dominated the East, Chicago towered in the Middle West, Johns Hopkins in the border states, and Stanford on the Pacific. Then after 1920 in a torrent came change.

And what a change, in a single brief generation! The public universities multiply so fast that in state after state they no longer rise as single peaks but as mountain ranges. California has eight of them in varying stages of growth; New York plans an equal number; Ohio has six state universities and three municipal universities; Illinois follows close behind. The richer states pour out money lavishly to improve their standards and facilities. Hence it is that the library at the University of Illinois vies with Yale's and surpasses Columbia's. Although within the memory of living men Johns Hopkins, Harvard, and Columbia had almost a monopoly of graduate study, now the public universities train a clear majority of the nation's graduate students. In some areas, educational leaders believe that the destiny of most small colleges is to become units in the state system. Chancellor Kimpton said in 1959 that Chicago was "scared to death of the University of California at Berkeley," referring no doubt to its ability to bid high for the best men; adding that Harvard and Yale "are scared too." Harvard is in fact no longer sure of its old primacy, for some competent observers believe that in range and height California is outstripping it.

Meanwhile, since 1920 no comparable growth swells the ranks of private universities. In all the wide region between the Mississippi and the Sierra Nevada no strong endowed university has arisen in our time save Rice. In the states bordering the Pacific none can be found save Stanford and (as yet limpingly) the University of Southern California. In short, the old-time imbalance of two centuries in favor of the private college and university has given way decisively to the predominance of the public institution; and this will assuredly increase.

Such a readjustment could not take place without friction and jealousy in some areas, alongside "a shared concern for the best goals of higher education" in others. The friction finds expression in complaints that are at times well justified; the jealousy is more often stimulating than deleterious. The whole situation is too complex for simple deductions. It varies so much from institution to institution, state to state, and section to section, that generalizations are dangerous. Some tentative judgments, however, may help us understand the nature of the present-day relationship between public and private seats of learning. These judgments pertain chiefly to developments since the last world war.

It is clear, in the first place, that more friction is visible between

the smaller endowed colleges and the state universities than between the larger endowed universities like Rice and the state giants. Some small colleges, indeed, have been fiercely vocal in their expression of grievances.

It seems equally clear that jealousy and friction have been least between those public and private universities which are most nearly comparable in means, equipment, and standards, such as Chicago and the University of Illinois, or Stanford and California at Berkeley. It is clear, too, that friction abates as the line between public and private institutions grows more blurred. This blurring becomes steadily more evident as private institutions accept state and national government grants and as public institutions build up endowments from individual donors. According to the latest *World Almanac*, the University of California has an endowment of $107,106,500, and Stanford an endowment of very nearly $98,000,000. In other words, California is rather more an endowed university than Stanford. It, of course, also has the state's resources behind it—and it needs them, for its enrollment is about thrice Stanford's.

In the third place, it seems evident that condescension, jealousy, and friction between large universities are best avoided not by differentiation but by a fair similarity of scope, aims, and standards; by a growing likeness, not a growing divergence. In the process of growing alike, the public and the private institution can learn much from each other. This statement will meet with violent dissent from those who believe that endowed universities ought to keep highly peculiar lineaments; that they should be marked by a greater specialization of effort, a sharper selectivity in choosing faculty and students, and a stronger sense of mission than public universities show. Perhaps they *ought* to be. But the fact is that all great universities, public and private, have grown and will continue to grow in similarity. This is partly because private universities seldom escape a certain desire for numbers, popular influence, and tuition-fee income. It is more largely because public universities, however often they are told to keep in their inferior places, also value specialization, selectivity, and a sense of mission. They, too, wish to be superior!

Finally, one interpretive judgment, however much it looks like a truism, is so important that it merits a decided emphasis. It is supported by a great deal of interesting history. This history shows that in the newer and less mature areas of the United States, strong private universities have exercised and continue to exercise an invaluable influence in stimulating and elevating state effort. They will retain that power for a long time to come. Intellectual and spiritual changes can be wrought in the great Southwest tomorrow akin to those which were wrought in the Old Northwest two generations ago. It is a

national misfortune that no strong endowed university exists in the Rocky Mountain belt to stimulate the states from New Mexico north to Idaho and Montana in doing far better by higher education than they have done. Such a university in the Pacific Northwest, too, might benefit the universities of Oregon and Washington quite as much as its own clientele.

The first interpretive judgment here stated, that respecting the specially difficult relations between some small colleges and some state giants, would require a volume for full treatment. From the Alleghenies to the Pacific the best of the small endowed seats play an invaluable role in education. Such colleges as Wooster, Appleton, Wabash, Knox, Grinnell, Colorado, and the Claremont group in California may be reckoned among the fine flowers of our civilization. These institutions, it is pleasant to say, often have close ties with the state universities. They explore co-operative relationships, sometimes fruitfully; they lean on the universities for faculty recruits, they borrow university professors for short periods, and they direct their best students to the graduate schools of Illinois, Wisconsin, or California. Earlham College cordially recognizes that the officers of Indiana University are expert and dedicated educators; Carleton College is not only a close neighbor but an admirer and friend of the University of Minnesota. Between President Sharvy Umbeck of Knox and President David D. Henry of Illinois go uncounted telephone calls, directing constantly a two-way traffic of counsel and practical aid. Nevertheless, the broad picture has its ugly lines.

Friction, as President Miller Upton of Beloit College writes, is manifest at three main points: the recruiting of students, the raising of funds, and competition in the "comparative image" or prestige. All institutions are anxious to obtain the best students available and therefore contend nervously for the ablest tenth, who will do most to inspire the faculty, burnish the academic reputation, and furnish in time a redoubtable alumni body. But the endowed college has to charge a high tuition rate, which steadily creeps toward an average of $1,500 a year; and the brilliant but poor youth has to weigh expenses. Surveys show that two-thirds of American families regard cost as the chief impediment to higher education. It is difficult for a small shop to sell even a superior article when a big store around the corner is giving much the same commodity away free. The fairest rectification of this situation is probably that which has been undertaken in California and Illinois and debated in New York; namely, the provision of state scholarships covering at least most of the tuition costs, and equally good in any institution, public or private. But this reform moves slowly.

Heads of many small colleges, in their bitterness, think of the big-

shouldered state universities as bruisers careless of the way they shove smaller people around. They feel an even greater resentment toward the ambitious new members of state systems that have been created out of former teachers' colleges. "Publicly," one college president writes, "these institutions make a great noise about the tremendous pressure on them from hordes of students who wish to attend. At the same time, they quietly spend large sums and devote many hours to soliciting students." He reports a count of seventeen state automobiles at the "college day" which one large high school of his area recently held.

Small colleges—and some large private universities as well—also feel aggrieved when they find their pleas for gifts falling on desks that are already white with letters from state institutions asking for aid; when their canvassers wait in the anterooms of corporation chiefs while state university agents, with every advantage of wealth, equipment, and massive alumni pressure behind them, walk inside to pick up the corporation check. The Associated Colleges of Illinois, an alliance of twenty-four private institutions formed to raise funds, once found East St. Louis a rich field. Then Southern Illinois University established a branch at Alton and moved to plant another in Edwardsville. To impress the legislature, it sought large gifts in this area. The small colleges thereupon found the best East St. Louis grain reaped, and only poor gleanings left in the stubble to the private institutions. A similar story comes from so many states that it is refreshing to find one, Ohio, which reports a unique harmony.

Even so famous and highly specialized an institution as Cal Tech has felt twinges of resentment against the state giants. In building a distinguished staff it has sometimes been hampered by the ability of Berkeley and UCLA to pay more for brilliant young associate professors. What is more, Berkeley can afford shinier laboratories and such costly installations as a cyclotron, beyond the private grasp. This does not mean that Cal Tech lacks distinctions of its own—it will soon have an unsurpassed computer—but it does imply an occasional disadvantage. When the University of California was launching something akin to a crash program at its new campus near La Jolla, it raided Cal Tech for some young experts lately brought from the East. This foray drew an indignant protest from President Lee DuBridge. It was quite proper, he wrote, for California to pay high salaries to tempt budding stars away from Harvard or Columbia; but it was outrageous to take them from Cal Tech after that school had made heavy sacrifices to import them.

The small colleges, however, offer a somewhat special problem. What of the relations between the great public and private universi-

ties; between Duke and North Carolina, Cornell and Rochester, Northwestern and Wisconsin, Berkeley and Stanford? It is on the whole a relationship giving mutual strength, declares the American Council on Education; but strength-giving in just what ways?

It has been happiest, we have said, when a fair parity of stature and a general similarity of aims and standards have been achieved. This statement contradicts a widespread assumption that public and private institutions will move most efficiently and harmoniously if they hew out separate paths. The private university under this assumption should stand for selectivity and the superior training of an elite; public universities, and especially land-grant institutions, should stand for service to the masses, including mediocre and ill-trained high-school graduates. Chancellor Kimpton said just this in 1959. He called for preserving "a world of difference," in which "the principle of private education would be careful selection, and the principle of public education would be broad inclusion." This theory I sometimes pondered at Columbia, thinking of New York University, a private institution of high numbers (near 40,000) and low standards, and City College, a public institution marked by rigid entrance requirements, a specially able and hard-working faculty, and a brilliant student body—largely Jewish. The theory there did not fit the facts. Nor did it fit them when I turned my gaze on Duke and North Carolina, Northwestern and Wisconsin, Stanford and California.

Once, doubtless, this theory of basic differentiation did hold good, but that day is gone. The fact is that Michigan, Wisconsin, and California nowadays select their students as rigorously as Chicago, Northwestern, and Stanford, though by different methods; they admit the highest one-eighth or at most one-tenth in high-school standing. If some qualitative difference exists in the Freshman years, it quickly disappears as the unfit are bumped off the wagon. In California and Stanford, avers Clark Kerr, the differences among graduate students are minimal for "fellowships and research assistantships effectively open both institutions to equal competition for top scholars." Differences between the University of Chicago and the University of Illinois, between Northwestern and Wisconsin, between Rochester and Cornell, are similarly minimal in point of quality. The before-noted statement by Pusey, Kerr, and other university heads for the American Council of Education, while correctly emphasizing the great diversity of American education, flatly contradicts Dr. Kimpton's point of view. It reads:

The nature of the difference among kinds of institutions can be and has been misrepresented. For example, it is simply not true to say that large institutions inevitably ignore the importance of the individual stu-

dent; that small institutions necessarily represent quality; that private institutions are for the sons of the rich; that institutional expenditures for a good education are any less in a public institution than in a private one; that one kind of American institution is "Socialistic," the other not; or that non-church-related institutions are unavoidably "godless." Such false antitheses defeat understanding and jeopardize the honest rivalry which should characterize healthy competition in a shared endeavor.

Any clear-cut differentiation, in fact, increasingly fades away. Once it may have been true that private universities were bolder in experimentation than public seats. They broke the path in graduate study, in establishing university presses and learned journals, and in founding pioneer departments and institutes. But the assertion is true no longer. Chancellor Charles B. Aycock of the University of North Carolina believes that Chapel Hill has been quite as "innovative and aggressive" as its neighbor, Duke University. And he offers an impressive array of supporting examples.

> Before Duke really had an opportunity to get going we had broken ground with the University of North Carolina Press, the Institute for Research in Social Science, the Institute of Government, the library extension program to the counties of the state, the Southern Historical Collection, the North Carolina Symphony Orchestra (the first in the country with state support), and learned journals like *Social Forces*. . . . Since World War II we have created from scratch a Department of Statistics, a Department of City and Regional Planning, an educational television station and program, a computation center, a systematic introduction of Russian studies in six departments, along with other developments, some of a procedural kind.

It is doubtless true that the large private universities do possess more flexibility than public universities. State institutions suffer clear restraints in the rules of the state budget authorities. President Fred H. Harrington at Wisconsin wrote me that he cannot transfer funds from one section of the university and cannot give fiscal support to new enterprises with the facility enjoyed by President A. Whitney Griswold at Yale. It is probably also true that in some instances private seats of learning can show the greater daring. No state university would have dared, for reasons both internal and external, to introduce so radical a change in undergraduate education as Chancellor Robert M. Hutchins' "New Plan" at the University of Chicago some years ago. In other instances, however, the richest public universities can show the greater daring in innovation simply because they have the ampler resources. President Wallace Sterling of Stanford pays tribute to the "increasing boldness of public institutions," exemplified

in the highly experimental character of the new campuses of the University of California as planned at Santa Cruz and Irvine.

It was once true that the atmosphere of teaching and research was freer in private institutions than in public seats; but heads of the largest and strongest state universities would vehemently deny that this is true today. Here again any real differentiation tends to disappear. "I think," writes President Sterling, "that it would make little difference to a faculty member whether he were pursuing research and teaching at Berkeley or at Stanford." The University of Illinois valiantly rebuffed an effort by certain legislators, some years ago, to force admission of unfit constituents to the Medical School. Wisconsin has for seven decades been a very Gibraltar in the defense of academic freedom in the broadest sense. If some state universities have had their seasons of difficulty, so have private institutions. One of the officers of the University of Kentucky, for example, points out that the Vanderbilt School of Religion recently encountered distinct troubles and he notes that Emory University has never been permitted to publish its contemplated work on John Wesley.

Beyond doubt the atmosphere of teaching and research is far more distinctly influenced by cultural and regional differences than by the private-public dichotomy. It is also clear that different types of pressure are exerted in different places. Public universities, whether state or municipal, are more likely to feel political pressures than their endowed neighbors. Private universities, on the other hand, are often more vulnerable to social and economic pressures. Both gain by increasing regional maturity. It was a sad page on which the story of the oath controversy in the University of California was written, but the faculty did resist the regents with success, and that page will not be written again. Louisiana State University has a rule that integration may not be discussed in classrooms except in direct connection with an academic subject. That rule is by no means strictly enforced and is withering away. Indeed, President John A. Hunter of Louisiana State, declaring that in the fifteen years of his association with the place few attacks on academic freedom have been made and none successfully, adds: "Both the people and the politicians in Louisiana have grown up in the past decade or two."

As the great institutions, public and private, grow more alike—and they do grow more alike—old-time attitudes of condescension and deference and old-time heartburnings disappear; equal co-operates with equal, teaching its rival what it can, and learning from its rival. Chancellor Aycock of North Carolina notes the fact that "many of my colleagues at Chapel Hill are closer to faculty members at Duke than they are to some members of their own faculty." The history of

the California Master Plan offers a dramatic illustration of co-operation among all the public and private institutions of higher education in the state; and important as was the part which state-college and university heads played in shaping it, that played by Vice-Provost Robert J. Wert of Stanford and President Arthur Coons of Occidental (two private institutions) was equally significant. Rivalry, however, should flourish alongside co-operation. "Both Tulane and Louisiana State," writes President Hunter, "are far better universities today than either would have been had not the other been established. This can be traced both to cooperation and rivalry, with rivalry, I am sure, the major contributor."

Our final interpretive judgment, that the leadership of strong private universities, by example and competition, can be invaluable when exerted in the less mature parts of the United States, has been illustrated in the past and will be illustrated again in the future. One of the greatest benefits ever conferred upon higher education in the United States was the founding of the University of Chicago by John D. Rockefeller in 1890. He had been strongly tempted to establish a great university under Baptist auspices on Morningside Heights in New York. In that area its influence would have been limited by the proud elder seats surrounding it on every side. But in the raw Middle West of Grover Cleveland's era it could cast its rays afar. The opening of Stanford in 1891–92 meant just as much for the Pacific Coast. Both institutions, under the leadership of two earnest, brilliant, and farsighted men, William Rainey Harper and David Starr Jordan, and with endowments theretofore unexampled, sprang into full-panoplied strength within a few years. Each radiated intellectual and spiritual inspiration over a wide section. Tulane, founded in 1886, was not so lustrous, yet we have just quoted a testimonial to its potency in the lower Mississippi Valley.

What a miracle the University of Chicago under William Rainey Harper wrought! Part of that miracle was within its own gray walls and inside the limits of the city that Harper believed would become one of the greatest in the world. Men then or soon of international renown were secured as teachers: A. A. Michelson in physics, Hermann E. von Holst in history, Albion W. Small in sociology, Paul Shorey in Greek, George Ellery Hale in astronomy, Jacques Loeb in biology, T. C. Chamberlin in geology, J. Laurence Laughlin in economics, James H. Breasted in Egyptology. The quarter system gave the institution year-round efficiency. For the first time university extension, a university press, and a chain of university affiliations were made an integral part of the educational plan. Emphasis upon research brought in a breath of tonic air. "The University will be patient,"

Harper told the faculty, "but it expects every man to produce." The first decennial of Chicago was celebrated by the laying of cornerstones for eight new buildings, and already after only ten years the university held a position of world prestige.

Meanwhile, however, the greater miracle had been wrought outside. Far and wide over the Northwest the university cast its rays. When word went out that Harper was dying of cancer, the president, faculty, and students of Notre Dame assembled in mass meeting to pray that he might be spared. Within a few years after the opening on the Midway the legislatures of the upper Mississippi Valley were taking a new attitude toward their state universities. Their pride stung, their spirit of emulation awakened, they resolved that what Rockefeller's millions and Harper's vision had achieved their own vast resources and their own chosen leaders could do as well or better. The head of the University of Illinois was astonished to see Governor John P. Altgeld walk into his office to inquire what the university needed. "I had never heard a governor talk that way before," he said. The great new private university on Lake Michigan was a fulcrum lifting the level of higher education throughout the broad area from Wendell Willkie's Indiana University to Willa Cather's University of Nebraska.

Of almost equal force was the influence of Stanford on the Coast. Though financially poorer than the state university at Berkeley, it constantly stimulated the growth and disciplined the standards of the larger institution. Its existence aided other public institutions. It always had some departments of clear superiority. It had a spirit all its own, vivid, idealistic, aspiring; the spirit mirrored in the pages of such alumni as Wallace Irwin, Robert L. Duffus, Frank E. Hill, Maxwell Anderson, and Bruce Bliven. Much of its distinction derived from President David Starr Jordan, who in power of inspiring students and influencing public opinion excelled any of the presidents of the public universities, even Benjamin Ide Wheeler. It put the state institutions of the Far West on their mettle, it spurred their trustees to seek abler faculty members, and it helped persuade legislatures to vote more generous appropriations.

All that Chicago did for the Midwest and that Stanford did for the Pacific Coast, Rice University can and will do for the rich and teeming Southwest.

FRITZ STÜSSI

On the Evolution of Science in Structural Engineering

In order to make any judgment about the development and meaning of "science" in civil engineering, it is necessary to take as our starting point the fundamental fact that this science is relatively young. Structural activity got along for many centuries without any scientific foundation for the design of its structures. Nevertheless, the civil engineering of that era produced two remarkable "golden ages" in bridge building, which is the most beautiful of all applications of structural engineering. The accomplishments of these periods, namely, under the Roman Empire and again in the eighteenth century, deservedly receive our sincere admiration even today.

In Roman times the building of bridges in stone and wood was a highly developed art which relied on empirical rules for the design. The knowledge and propagation of these rules were invested, at least initially, in the clergy, whose professional title (*pontifex*—bridge-maker) was even derived from bridge-building. The decline and fall of the Roman Empire brought a similar fate to the art of bridge-building: the political necessity as well as the material means for the construction and maintenance of a road system such as had been required for the administration of a large empire was henceforth lacking.

A considerable number of Roman stone bridges are either still in use today (for example, the Augustus Bridge in Rimini) or are at least so well preserved that they provide us with a vivid picture of the advanced level of the Roman art of bridge construction (for example, the Pont du Gard near Nîmes, an aqueduct in southern France [Pl. I]). But these structures also show us the limitations of what the Romans were

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able to do and thereby provide us with our first indication of the significance of science in structural engineering: the Roman arches are semicircular and of limited span, slightly exceeding 130 feet in only two structures. Any further development by increasing the length of span and simultaneously decreasing the arch's ratio of height to width is possible only by means of an arch more suitably shaped to sustain the inner forces. The semicircular shape tells us that the Romans did not possess any valid concept of the interplay of forces here or of the thrust line. We may regard as truly astonishing the fact that the Roman accomplishments in bridge construction, based as they were on the empirical rules of a manual trade, were possible at all, in the total absence of the knowledge which, from our present-day point of view, comprises the very fundamentals of engineering science.

We have Leonardo da Vinci (1452–1519) to thank for the first big step toward a thorough understanding of the interplay of forces in an arch span. He clearly recognized the horizontal force's effect and its significance for the bearing capacity of arched structures, and he depicted this lucidly in a series of sketches (Pl. II) (1). This realization constituted the necessary groundwork for the progress of stone bridge construction beyond the level of Roman times, as we realize when we see a further sketch of Leonardo's which is to be found in Manuscript L (2). We have here a sketch for the design of a stone bridge which sounds like a vision of enormous daring, surpassing not only anything of Leonardo's day and age, but also anything that has been carried out in the field of stone bridges up to the present. This sketch is reproduced in Plate III, backwards, so that Leonardo's text, written in mirrored script, may be more easily legible: "Ponte da Pera a Gosstantinopoli, largo 40 braccia, alto dall' acqua braccia 70, lungo braccia 600, cioè 400 sopra del mare e 200 posa in terra, faccendo di se spalle a se medesimo [Bridge from Pera to Constantinople, 40 cubits wide, 70 cubits high over the water, 600 cubits long, 400 of which over the sea and 200 on land, forming its own shoulders]." (1 cubit = *ca.* 2 ft.)

Professor Franz Babinger (3) of Munich has convincingly demonstrated that this sketch represents the design for a bridge across the Golden Horn, for the construction of which Leonardo had commended himself as architect to the Turkish Sultan Bajezid II. If we check Leonardo's plan with a complete calculation, we find that the structure could have been built just as he envisioned it, with a span of over 800 feet (4). We are well aware of the enormous difficulties which would have to be overcome in the erection of such a gigantic structure. In addition, special problems arise as a consequence of the

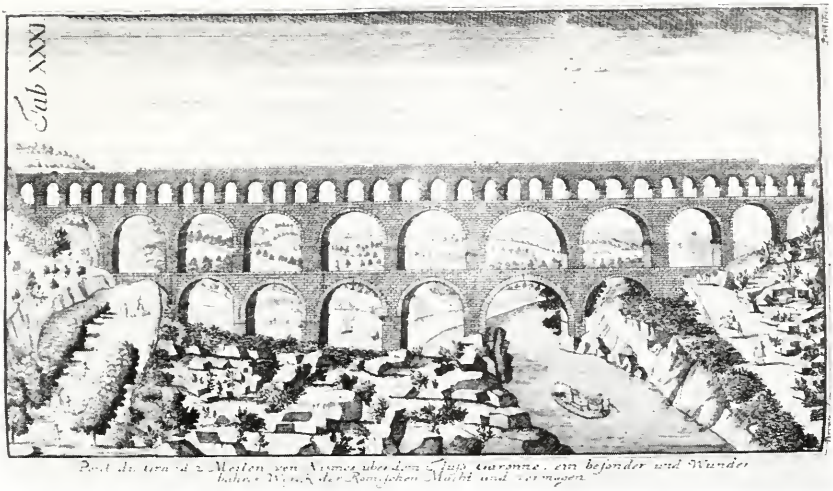

PLATE I.—The Pont du Gard near Nîmes

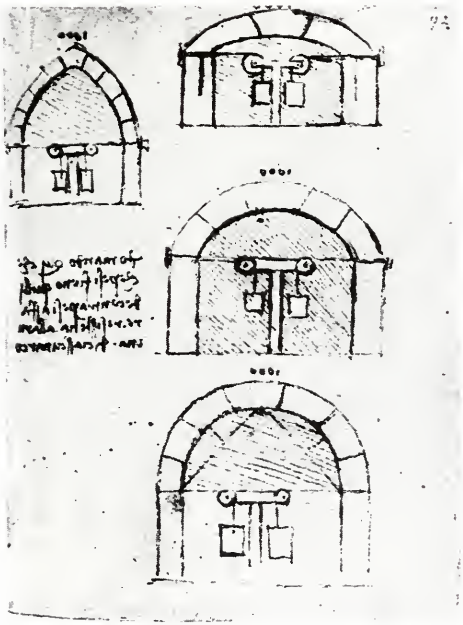

PLATE II.—Leonardo da Vinci's sketches of arches

Plate III.—Leonardo da Vinci's sketch of a proposed bridge from Pera to Constantinople.

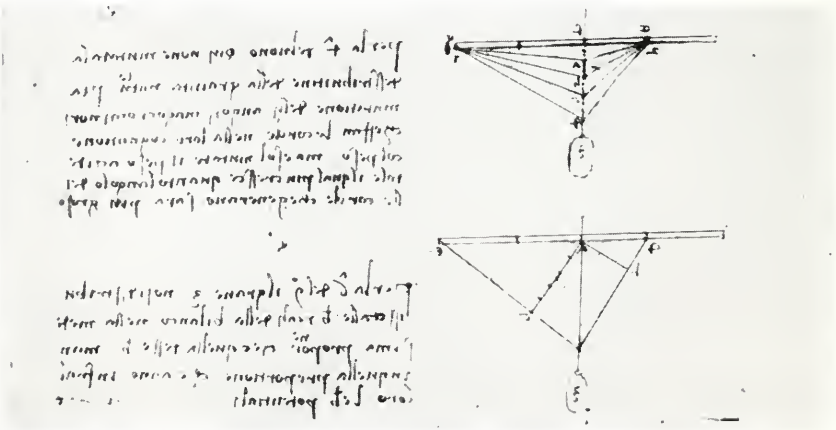

Plate IV.—Leonardo da Vinci's depiction of a static movement of forces

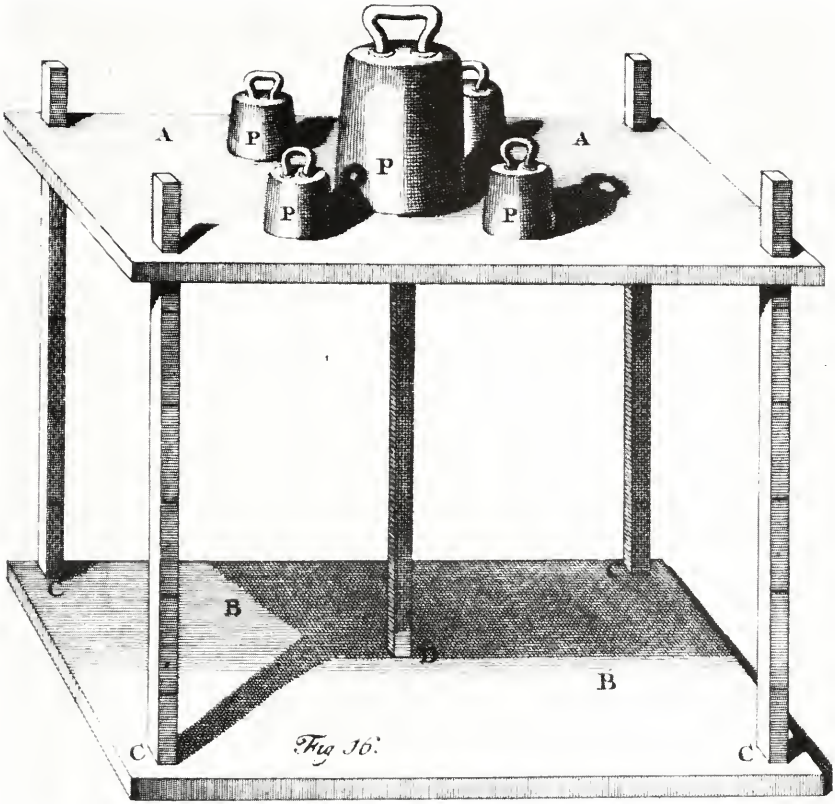

Plate V.—Apparatus for buckling research by Peter van Musschenbrock

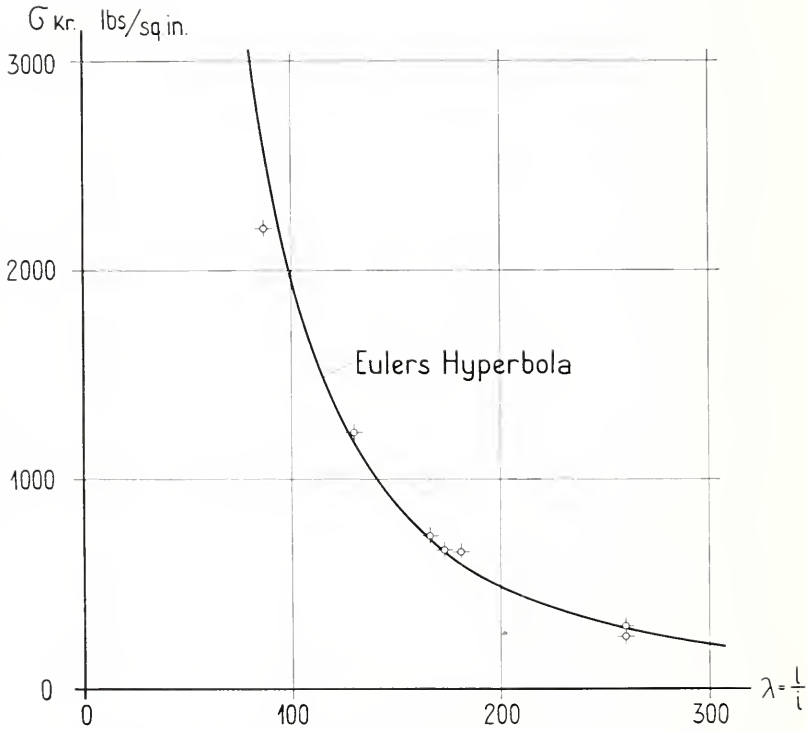

PLATE VI.—Results of van Musschenbrock's buckling experiments

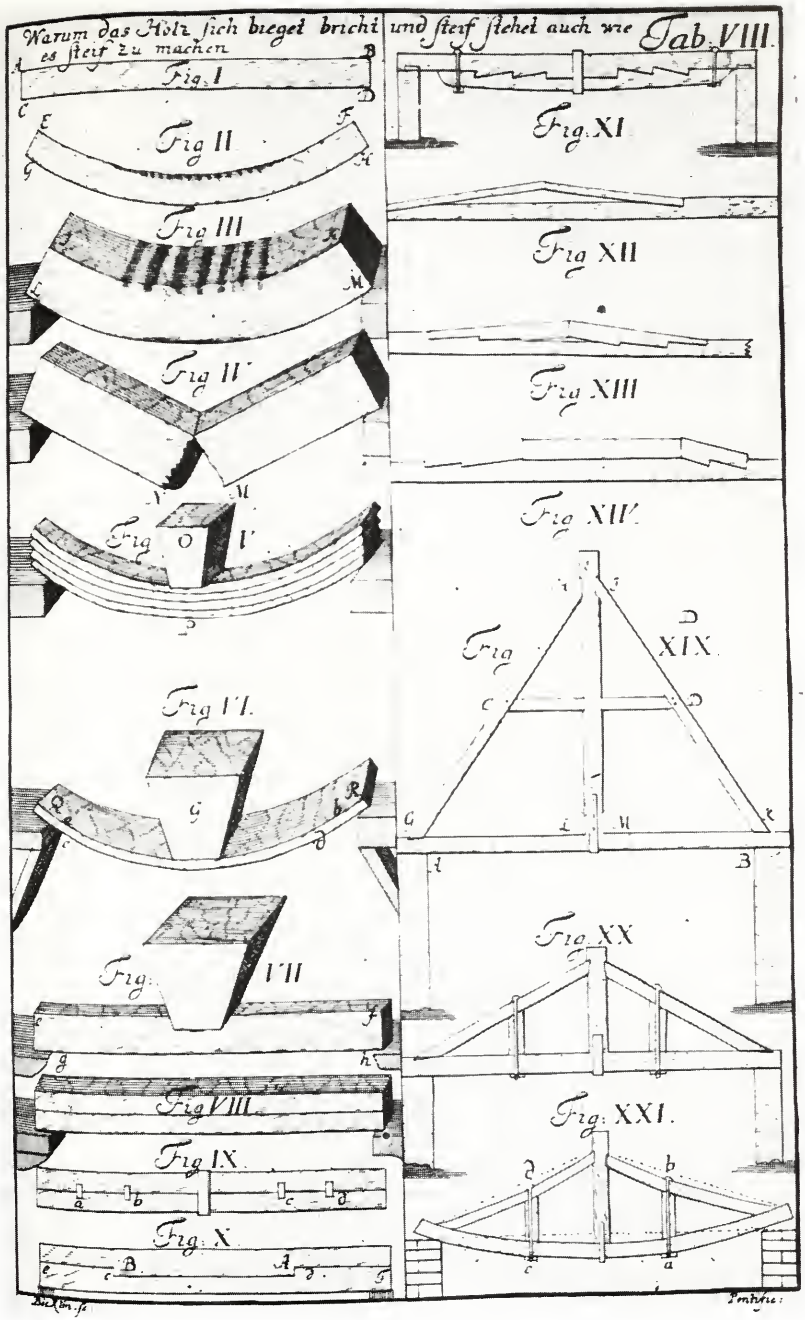

PLATE VII.—Illustration from bridge-construction book by Jakob Leupold published in 1726.

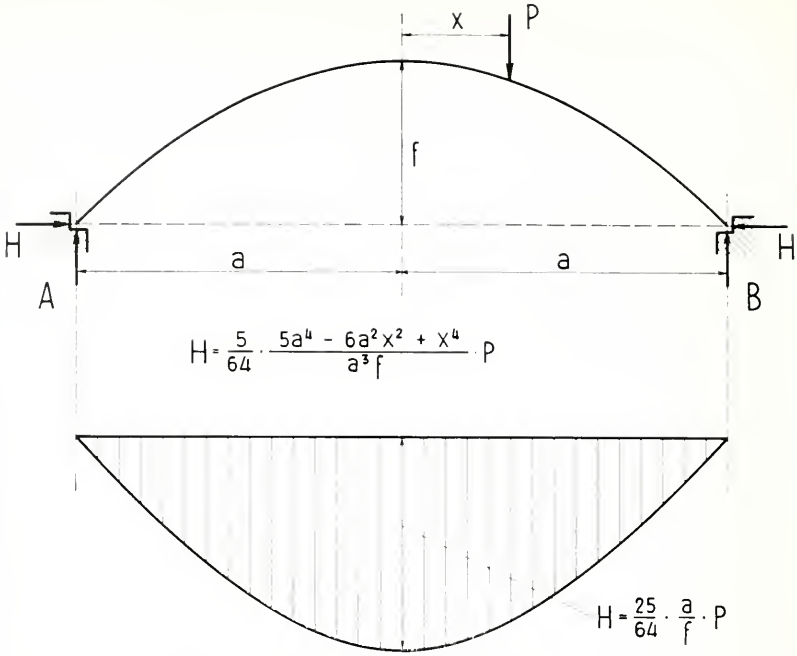

PLATE VIII.—Navier's solution for the influence line for horizontal thrust

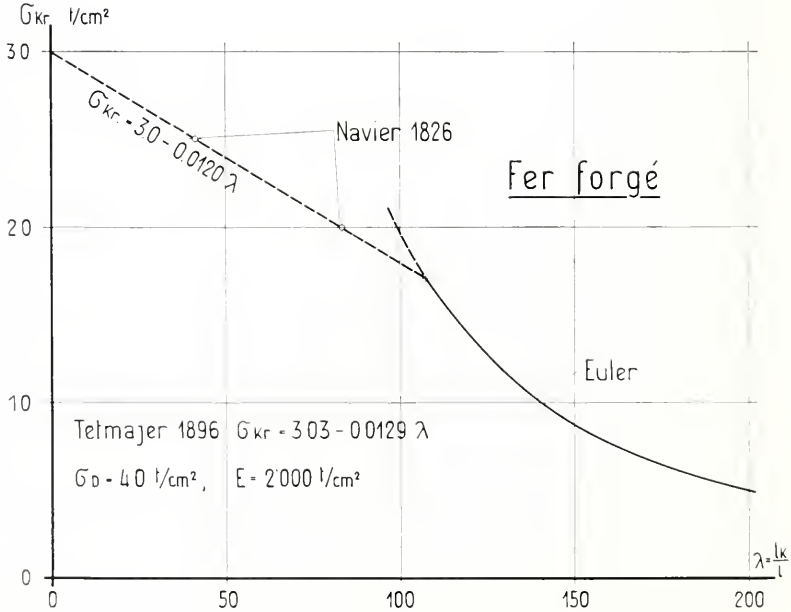

PLATE IX.—Buckling stress for columns

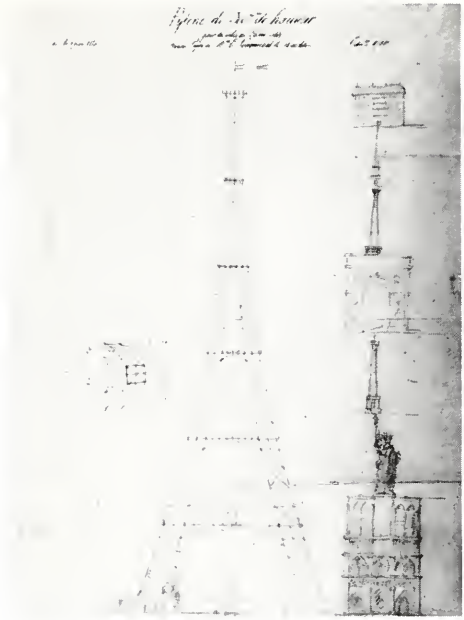

Plate X.—Maurice Koechlin's first sketch of the Eiffel Tower

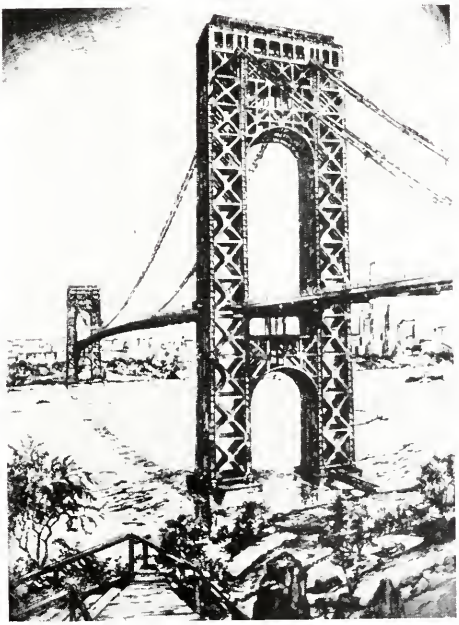

Plate XI.—George Washington Bridge, designed by O. H. Ammann

unfavorable soil conditions at the Golden Horn. Sultan Bajezid did not accept Leonardo's suggestions, and the bridge was not built. Consequently, we will never know whether fate saved Leonardo from a disaster or unjustly robbed him of the fame of having been one of the greatest bridge-builders of all time.

One of Leonardo's further accomplishments in this field is the correct formulation of the static moment of forces with a random orientation. A particularly impressive proof of Leonardo's creative intuition is the fact that he depicted this relationship with the help of a loaded cable (Pl. IV) (5). His sketch thereby portrays the basic form of the funicular polygon, to the significance of which for the engineering sciences we shall return later. For the present, we may mention briefly that Leonardo also worked out correct conceptions of the bending of beams, the buckling of columns, the construction of falsework, and numerous other problems.

The question arises here whether or not we can designate these discoveries of Leonardo as "science." I personally have no hesitation in answering this question in the affirmative. Leonardo arrived at his discoveries by observation and contemplation; observation and contemplation together constitute the basis of research activity in all branches of the natural sciences. Even though he did not succeed in attaining a definitive mathematical formulation of many of his discoveries because the necessary tools, such as differential and integral calculus, simply were not available at that time, still, Leonardo was, more than anyone before him, entitled to lay down the criterion: "Studia prima la scienza, e poi seguita la pratica, nata da essa scienza [First study science, and after that comes the practice which is born from this science]." When Leonardo penned these words, he had civil engineering specifically in mind, as we see from another quotation of his: "E però, o studianti, studiate le matematiche e non edificate sanza fondamenti [And therefore, ye students, study the mathematical sciences and don't build without a foundation]." With such precepts as these, Leonardo brought about the fundamental transition from empirical building as a manual trade to construction on a scientific basis and thereby became the founder of our present-day engineering science.

Leonardo's call for a combination of theory and practice in civil engineering was not brought to fruition for the time being, namely, for about three hundred years. Although his notes were not published during his lifetime and his discoveries were not generally known, the problems that he had touched on were pursued further. Pierre Varignon (1654–1722), for example, picked up where Leonardo had left off with the construction of the funicular polygon, Galileo

(1546–1642) continued the investigation of the bending of beams, and Peter van Musschenbroek (6) did research on the buckling problem by experimenting with wooden bars (his apparatus is depicted in Pl. V). The results of his buckling experiments on ashwood bars are summarized in Table 1 and are portrayed in Plate VI in the form customary today by means of the buckling stress curve.

For an assessment of these experimental results, it is necessary to bear in mind that the boundary conditions of the columns used are not unequivocally determined. Furthermore, the inch and pound used by van Musschenbroek do not exactly correspond to those of the Anglo-Saxon system. But what can be seen with full clarity (and this speaks for the care in the carrying out of the experiments) is the fact

TABLE 1

No.	l (in.)	h (in.)	b (in.)	P_{kr} (lb.)	i (in.)	λ	F (sq. in.)	σ_{kr} (lb/sq in)	$\sigma_{kr} \times \lambda^2$
226.....	18	0.24	0.25	15	0.0693	259.7	0.0600	250	$16861 \cdot 10^3$
227.....	6	.24	.25	132	.0693	86.6	.0600	2200	16499
228.....	12	.24	.34	55	.0693	173.2	.0816	674	20219
229.....	9	.24	.34	100	.0693	129.9	.0816	1225	20671
230.....	18	.24	.42	30	.0693	259.7	.1008	298	20098
231.....	11.5	.24	.42	74	.0693	165.9	.1008	734	21578
232.....	11.5	0.22	0.55	80	0.0635	181.1	0.1210	661	21679

that the experimental values correspond quite closely to the hyperbola of Euler with $\sigma_{kr} = (19660/\lambda^2) \cdot 10^3$ lb/sq in. Peter van Musschenbroek thereby found experimentally a significant fact about the problem of elastic stability.

Such experimental results as these, together with experience gained and observations made on executed structures or even on models, have made their way into construction practice, not in the form of scientifically derived calculation formulas, but in the form of empirical design rules. Such rules have rendered immense service as practical guides for the actual practice. Indeed, they form the basis of the great accomplishments in eighteenth-century bridge construction. Plate VII, which is taken from the bridge-construction book of Jakob Leupold (7), shows that even at that time quite useful conceptions of the behavior of composite beams were available.

The great accomplishments in eighteenth-century bridge construction are no longer those of a group, as in the case of the Roman clergy. These accomplishments, relying on the experience and discoveries made empirically in the manual trades, were rather the personal accomplishments of certain exceptionally gifted persons in the con-

struction profession who were able to fill the gap of what was still lacking in the scientific arsenal with their own personal gift of an intuitive grasp of the interplay of forces. In the front ranks of these stands Jean-Rodolphe Perronet (1708–94), the builder of a whole series of exceptional stone bridges, including the Neuilly Bridge across the Seine in Paris. Perronet was the founder and first director of the École Royale des Ponts et Chaussées, the first technical university in the world, which was established in Paris in 1747. Also in the front ranks stands Johann Ulrich Grubenmann (1709–83), who built the remarkable bridges over the Rhine in Schaffhausen and over the Limmat in Wettingen (both in Switzerland). The prominent English engineer Thomas Tredgold (1788–1829), in his book *Elementary Principles of Carpentry*, had this to say: "The French Army in 1799 destroyed the celebrated bridge across the Rhine at Schaffhausen, but the fame of Grubenmann the carpenter will long continue; and the form of this excellent specimen of the art will only cease to be remembered when carpentry itself no longer exists." Grubenmann and Perronet were no theoreticians but downright practical men who, however, not only had the technical knowledge of their time at their command, but above and beyond that also possessed the rare gift of creative intuition to a degree which has seldom been repeated. For the second time, therefore, the art of bridge construction had reached a point beyond which it was impossible to go with the same means, that is, without new knowledge of the strength of structural elements.

Such knowledge presented itself, however, in the works on analytical mechanics of the great theoreticians such as Jakob and Daniel Bernoulli, Leonhard Euler, Joseph-Louis Lagrange, and others. The construction practice paid no attention to these works, however, largely because their mathematical formulation made them virtually unintelligible to the builder. On the other hand, these theoreticians had no interest in concocting aids for the design of structures. The analytical mechanics problems that they dealt with were rather examples with which mathematical methods could be developed. A typical example of this tendency is the derivation of the buckling formula by Leonhard Euler in 1744. This derivation, which, for the first time on a theoretical basis, turned up the fascinating peculiarity of the stability problems, that disturbances however small can lead to finite results, namely, buckling, appears in an appendix, "De curvis elasticis" ("On Elastic Curves") to Euler's principal work on maxima and minima (8). The elastic curves that he investigated serve only as applications of the mathematical methods that he developed. As for the quantity which is indispensable for the practical application, namely, the bending stiffness, Euler defined it but did not determine

its numerical value, and his definition is not correct (proportional to the square instead of the cube of the thickness for a beam with rectangular cross section, $I = bh^3/12$). This proves that a practical application was not important to Euler. Granted, Euler clearly recognized the connection between his formula and the bearing strength of columns, and for this reason he took up the subject again (9) and even gave a simplified derivation limited to small deformations, but the formulation of a ready-to-use formula applicable in practice was not carried out by him here, either. It is not my intention in any way to depreciate the magnitude of Euler's accomplishments either in general or in particular in the case of his discovery of the buckling formula; on the contrary, this accomplishment must be estimated all the more highly, inasmuch as the difficulties which he had to overcome were not only on the mathematical side but lay also to a considerable extent in the fact that the concepts of the theory of bending which are familiar to us today were at that time still unknown.

Thus we may describe the level of our science at the turn of the nineteenth century. Construction, empirically oriented as it was toward the manual trades, and the mathematically oriented science of analytical mechanics developed completely independent of one another. Epistemologically and methodologically they were separated from one another by an abysmal contrast. This contrast is crassly expressed in a malicious remark transmitted by the previously mentioned English engineer Thomas Tredgold: "The stability of a building is inversely proportional to the science of the builder" (10). Nowadays we smile at this remark and reject it as an overstatement, but upon closer examination of the way things stand even today, we have to concede that it contains at least a particle of truth.

It was in this situation that the outstanding accomplishments of the great French engineer Louis Navier (1785–1836) came to the fore. These entailed not only the fulfilment of Leonardo da Vinci's old call for a synthesis of science and practice to an extent comprehensive for the needs of the time, but also simultaneously of the fundamental basis for the entire further development of the science of civil engineering. In his two principal works (11) on suspension bridges in 1823 and on the strength of materials in 1826, he developed, for the first time in the history of mankind, a systematic, scientifically well-founded theory of design for civil engineering. This accomplishment was only possible thanks to the fact that Navier was extraordinarily gifted in two directions: he was not only an excellent engineer but also a highly gifted mathematician. Neither an engineer without Navier's mathematical bent nor a mathematician without his constructive talent would have been able to render such an accomplish-

ment. On the one hand, Navier had the technical tools of his time at his command; he revised, improved, and expanded the books of Bernard Bélidor, *La Science des Ingénieurs* ("The Science of the Engineer") and *Architecture Hydraulique* ("Hydraulic Architecture"), as well as E. M. Gauthey's *Traité de la Construction des Ponts* ("Treatise on the Construction of Bridges"). He collected all the available literature on the behavior of the structural materials of his day and age and summarized them systematically. On the other hand, he also made a thorough and careful study of the investigations in analytical mechanics starting with Galileo and continuing with Jakob Bernoulli, Leibniz, and Euler, up through Lagrange and Charles Coulomb.

Not only did Navier carry out the synthesis of the various kinds of knowledge available at the time but he also made major new contributions of his own to the development of our science. Best known is the theory of bending, which is still to this day named after Navier, and which gives us the stresses and deformations of a beam subjected to bending. It is likewise well known that he was the first to solve the differential equation of the elastic plate; we also have to thank him for the fundamentals of the membrane theory of shells, such as was required for containers of liquids at the time. He dealt with the calculation of the unstiffened suspension bridge, of bridge spans in stone, and of simple and composite structures in wood or even in iron. It is remarkable that the solution of a whole series of statically indeterminate problems, such as the continuous beam and the two-hinged arch, also leads us back to Navier. He established that the behavior of such structural systems, regarded from the point of view of the equilibrium of forces, is indeterminate, but that this indeterminateness would completely disappear if the structures were regarded as elastic, that is, if the deformations were taken into consideration. On the basis of an investigation of this sort, Navier even succeeded in obtaining an influence line for the horizontal thrust. Disregarding the influence of the axial force, he gives this, using the designations in Plate VIII, as:

$$H = \frac{5}{64} \cdot \frac{5a^4 - 6a^2x^2 + x^4}{a^3 \cdot f} \cdot P .$$

Finally, one more significant accomplishment of Navier's deserves to be mentioned: he established that for short, compressed columns, not the stability (as per Euler) but rather the strength must be the decisive factor. Even if he did not yet have at his disposal the fundamentals from which the entire inelastic range of buckling could be precisely formulated, still, on the basis of the few experimental results which were available to him at the time, he supplied certain special values for the buckling stress of a short column. These values are as

follows for bars of rectangular cross section made of forged iron with a compressive strength $\sigma_D = t/\text{cm}^2$:

$$l_k = 12h : \sigma_{kr} = \tfrac{5}{8} \cdot \sigma_D = 2.5t/\text{cm}^2$$

$$l_k = 24h : \sigma_{kr} = \tfrac{1}{2} \cdot \sigma_D = 2.0t/\text{cm}^2 .$$

If we set $h = 3.464 \cdot i$ and construct through these two points:

$$\lambda = \frac{l_k}{i} = 41.57/83.14, \qquad \sigma_{kr} = (2.5/2.0t)/\text{cm}^2,$$

as first approximation, a straight line, we get $\sigma_{kr} = 3.0 - 0.0120\ \lambda$ in t/cm^2 for the inelastic domain, whereas for the elastic domain Euler's buckling stress curve $\sigma_{kr} = (\pi^2 \cdot E)/\lambda^2$ holds valid (Pl. IX).

Evidently these discoveries of Navier's were not taken to heart by the engineering profession, and it took a good seventy years until F. Engesser (12) published his two theoretical solutions for inelastic buckling. We designate these two solutions as the "Engesser-Kármán solution" and the "Engesser-Shanley solution," in accordance with the later work of Theodor von Kármán (13) and F. R. Shanley (14). They belong together and constitute the upper and lower limits of inelastic buckling (15). At about the same time as Engesser's theoretical investigations, Ludwig von Tetmajer (16) carried out his comprehensive buckling experiments and circumscribed the inelastic domain with "Tetmajer's straight line"; for forged iron, he gives the value $\sigma_{kr} = 3.03 - 0.0129 \cdot \lambda$ in t/cm^2, which is obviously an astonishingly good confirmation of Navier's discoveries. But even in the face of these new discoveries regarding inelastic buckling, which were virtually custom tailored to the needs of civil engineering, the construction practice evinced a highly regrettable inertia, as is unfortunately all too often the case. The collapse of the Hamburg gas tank in 1909 could have been avoided if the limits which Navier, Engesser, and von Tetmajer placed on elastic buckling had only been heeded.

In most of his problems Navier derived a solution with a closed mathematical formulation. In certain cases in which this was not possible, he gave a solution by iteration with successive approximation or even an approximate solution which lay on the safe side. Thus he demonstrated not only his great flexibility in the choice of calculating methods combined with his keen insight for what was essential, but he also demonstrated that he was interested only in setting up a reliable and workable basis for safe construction.

One essential feature of the engineering science founded by Navier shows up in the title of his second principal work, *Résumé des leçons sur l'application de la mécanique* . . . ("Summary of Lessons in Ap-

plied Mechanics . . ."). We are dealing here with an *applied science* which does not exist for itself alone but only in connection with its purpose of providing the basis for a reliable and safe design, solely as the servant of the art of structural engineering. We simply have to accept this limitation, in consideration of the enormous responsibility that the engineer must bear for human life and for property. But the need for economy of thought formulated by Ernst Mach also holds for this "servant science," as it does for every scientific activity. Navier fulfilled this need within the framework of the possibilities of his time.

The further development of statics in its most important stages from Navier up to the present can be roughly characterized by the following steps:

In connection with the development of wooden-bridge construction in America, the bridge systems of Stephen H. Long, Ithiel Town, and William Howe were developed, the last of which, a truss with a prestressed double system of struts, is still today a very important element of wooden construction. Concomitant with this development, various useful procedures for the calculation of trusses were developed almost simultaneously by S. Whipple (17), F. W. Schwedler (18), Karl Culmann (19), and, as Stephan Timoshenko has demonstrated, by D. J. Jourawski in Russia (20). The virtually simultaneous development of a truss theory by four different engineers who can hardly be considered to have had anything to do with one another can be explained not only by the pressing need of the construction practice of the time for such a method of calculation, but equally well by the fact that the premises for such an investigation were already available and needed only to be worked out and applied in the proper form.

The next big significant step was contributed by Karl Culmann (1821–81) in connection with his position as a member of the faculty of the newly-founded Federal Polytechnic Institute of Switzerland. With his "graphical statics" (21) he introduced graphical methods for the calculation of structures, founded on geometrical relationships of the newer geometry, which were immediately comprehensible to the designer, employing the draftsman's language familiar to the engineer. Without a doubt, the force and funicular polygon is one of the most important discoveries of these new graphical statics. Prior to Culmann, this construction had been used to find the resultant of a group of forces acting in the same plane or to represent the shape of a loaded cable. Culmann's decisive step was to add to this construction the line named after him, thereby obtaining from one and the same geometrical construction not only the reactions at the supports

but also the bending moments and the axial and shear forces of a loaded beam. When we know that the moment M and the load per unit length p are connected mathematically by a differential equation of the second order, namely, $M'' = -p$, then, by analogy, the funicular polygon turns out to be a sort of integral machine, giving us the second-order integration of loading functions in the simplest manner, yet with complete strictness. Thanks to this analogy, the funicular polygon can be used for deriving a function y from its second derivative, y''.

One cannot easily overestimate what a fruitful influence graphical statics had on the development of structural engineering in the practical as well as the theoretical direction. The easy use of the geometrical representation of forces led to the design of structures on the basis of a "statical calculation" as the established norm rather than with empirical rules. Prominent bridge-building firms endeavored to get former students of Culmann as designers for their technical divisions. One of the most remarkable structures stemming from the school of Culmann is certainly the 1,000-foot Eiffel Tower in Paris, erected for the World's Fair of 1889. Plate X shows the first design sketch made by Culmann's pupil, Maurice Koechlin (22), who, while in the employ of the Eiffel firm, was in charge of the design of this structure, one of unprecedented audacity for its time.

As theoretical products of Culmann's "graphical statics," two deserve particular mention. The first is the force diagram of Cremona (23); the second is the work of Wilhelm Ritter, Culmann's pupil and successor, who expanded and augmented the heritage of his teacher in his four-volume work, *Anwendungen der graphischen Statik* ("Applications of Graphical Statics") (24). Of further significance is the fact that Heinrich Müller-Breslau gave his book a title which shows Culmann's dominating influence: *Graphische Statik der Baukonstruktionen* ("Graphical Statics of Structures") (25), even though he employed analytical methods just as much as graphical ones in this major textbook in which he comprehensively systematized the calculation methods of structural statics.

Not to be passed over are the numerous brilliant contributions with which Otto Mohr (26) has enriched our knowledge of statics and strength of materials as well as the contributions of Timoshenko (27) in the fields of strength of materials and stability problems.

The civil engineer's task is to create structures which satisfy the demands of utility, durability, aesthetics, and economy. A structure that we erect today should still be rendering useful service generations from now. Within the framework of this generalized task, "science" has the task of calculating the inner stresses resulting from the

external loads as may be expected and of determining that the chosen structural materials are capable of sustaining these inner stresses with a sufficient margin of safety any number of times or for any desired length of time. By itself, this science is not capable of creating any structures. It is not creative, but it provides an auxiliary means, a tool of the designing engineer which enables him to examine a particular structure (whether already standing or only in the design stage) with regard to its safety and rigidity.

For the solution of the design problem, we have at our disposal three groups of relationships which nowadays are safely founded. These are, first, the equilibrium conditions, second, the deformation conditions, and third, the relationships which, for the structural material in question, hold valid between the forces and stresses on the one hand and the deformation on the other hand. Within the elastic domain, Hooke's Law and its corollaries provide us with this third group of relationships. A statically determinate structure is one which can be solved by using the equilibrium conditions alone; the deformation can then be calculated in a second step. In the more general case, however, the three groups of relationships have to be combined in such a way that they lead to the most perspicacious equations possible for the solution. When dealing with a finite number of structural elements, for example, the individual spans of a continuous beam, one obtains a system of simultaneous equations which are usually linear, in which forces and/or deformations can appear as unknowns. Strange to say, structural engineers in practice generally tend to shy away from the solution of such systems of equations, even though the solution with the elimination method of C. F. Gauss (1777–1855) (28) presents no fundamental difficulties, but at most a somewhat laborious task in the case of a large number of unknowns. Here electronic computers with their extraordinary capacity for work can render valuable service to structural engineering as well.

On the other hand, when equilibrium and deformation investigations have to be carried out with regard to differential elements of a structure, the equations for its behavior turn out to be differential equations, either one or several simultaneous ones. Here we run across one fundamentally important feature peculiar to structural engineering. In mathematics and analytical mechanics it is normal to find the solution of the differential equations analytically with the tools of higher mathematics. Indeed, the solution of a hitherto unsolved differential equation is one of the goals of the research in higher mathematical analysis.

The differential equations with which one is confronted in structural engineering are mostly in the form of total or partial differential

equations of the second or fourth order, often with variable coefficients and also with any sort of perturbation term. A closed mathematical solution is usually possible only in the simplest cases, which do not include the structural forms and the cases of loading which have to be dealt with in actual practice. In this connection it is worth recalling that for the solution of the differential equation of an elastic plate of constant thickness under the simplest support conditions, even an evenly distributed load leads mathematically to an infinite double series. This constitutes a basic violation of the principle of economy of thought. One further example deserves to be cited: the buckling of a column of constant cross section, hinged at both ends, with a linearly variable axial force (resulting from taking the column's own weight into consideration) leads to a differential equation which not even the great Leonhard Euler was able to solve. Analysis provides us with closed solutions only for relatively simple differential equations. This we see quite distinctly from the fact that the functions $\sin x$, $\cos x$, $\sinh x$, $\cosh x$, e^x and e^{-x}, for which tables exist in our handbooks, are all solutions of an initial value problem expressed by the simple differential equation

$$y'' \pm y = 0$$

with various initial conditions.

On the basis of these considerations, it becomes apparent that we need not only analytical but also numerical methods for the solution of the differential equations of structural statics. The latter methods do not tell us much about the mathematical nature of the function we are looking for, but they do give its numerical value in as many points as we want. A numerical solution of this sort makes use of the fact that the derivatives y', y'', etc., in the differential equation we want to solve can be eliminated by expressing them in terms of the unknown function y itself. The differential equations thereby is transformed into a system of determinate equations in the unknowns y_{m-1}, y_m, y_{m+1}, etc. For most of the differential equations that we meet in structural statics, the essential step consists of eliminating the second derivative, y''. This may be accomplished by expressing y'' in point loads, whereby, in the case of points chosen equidistant, the funicular polygon equation $y_{m-1} - 2y_m + y_{m+1} = \Delta x \cdot K_m\ (y'')$ can be used. It turns out that a whole series of problems can be solved with this method without difficulty, problems which, with analytical means, either cannot be solved at all or at best only by long and laborious operations. These numerical methods have the further advantage of being based on fundamental concepts which by their very

nature are familiar to the engineer who has to carry out the calculation (29).

The particular nature of the structural engineer's methodology manifests itself nowadays also in certain more recent problems regarding the behavior of materials in structures. In connection with the present-day developments in the structural field, certain processes taking place over a long period of time, such as fatigue, creep, relaxation, and creep strength take on increasing importance. We are concerned here with physical processes which are also of interest to the physicist, who seeks to explain these phenomena by means of the basic laws of physics in order to arrive at a reliable prediction of the behavior of the material over a long period of time. On the basis of our present-day knowledge, this will not be possible for years to come. Consequently, the engineer, who has to know today what to expect, is compelled, as is, for example, the biologist, to look for a solution to these problems on a phenomenological basis. It has been possible to establish that certain of the first relationships found by this way can be regarded as correct (30).

The future tasks of the science of structural engineering are therewith also sketched, at least in broad outline. It has been and remains our task, taking into consideration the real behavior of the material, to predict as reliably as possible the behavior of our structures, even in cases in which new structural forms are developed, in order to build safely.

In conclusion, let us cast a glance at one of the most outstanding engineering works of our time, the George Washington Bridge across the Hudson River at New York City (Pl. XI). This bridge, designed by O. H. Ammann, doubled in one stroke the realized length of span. Even though still longer spans are already possible nowadays, the George Washington Bridge will still, for this reason, remain a significant milestone in the development of bridge-building for all time to come. The need for a bridge across the Hudson had been pressing since back in the eighties of the last century, but all previous designs, even though carried out by prominent engineers, failed to be transformed into reality because they did not solve the problem economically. This honor was reserved for Ammann's plan.

O. H. Ammann's solution was based on an idea which was, perhaps, at first purely intuitive; namely, that a sufficiently heavy cable, by itself, without any stiffening elements, is sufficiently rigid to sustain even moving traffic loads with sufficient traffic safety. Many years of hard work, years of worry and doubts, however, may lie between the first idea and the proven fact, between the first, still sketchy notion and the completed design and the erection. The

transformation of the intellectual discovery into a structure so enormous that it is to be used by thousands of persons at one time called for the creative courage characteristic of great engineers. O. H. Ammann's George Washington Bridge is one of the structures with which was brought to realization that for which generations of engineers had prepared and laid the groundwork. It is the complete synthesis of intuition, experience, knowledge, and ability, which is necessary for accomplishing great engineering works. The theory, however, is purely a servant to the art of structural engineering, which dominates in this synthesis, and which is, in turn, also a servant to human civilization.

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ALBERT SZENT-GYÖRGYI

Horizons of Life Sciences

If the history of mankind is represented by one continuous rising line, then the present is but a point on this line, a point which divides the past from the future.

There is a curious difference between the two parts of this curve: while the past seems clear, logical, governed by some sort of rigorous logic of its own, the future, even the morrow, seems to be shrouded in darkness. There is but one way of finding out something about the future: by studying the past and then trying to extrapolate, that is, to extend the curve of the past toward the future. As a scientist, I am most interested in this history of science and its relation to the story of man, which will be the subject of my talk.

The history of science is composed of three periods: antiquity, the period of classical science starting with the Renaissance, and the period of modern science which started at the turn of this century. What characterizes the *science of antiquity* is the naïve faith in the perfection of our senses and reasoning. What man sees is the ultimate reality. Everybody, being by necessity the center of his universe, knew there was no doubt that ours is a flat earth and man is the center, as expressed in the cosmology of Ptolemy. If we touch something we find it either hard or soft, wet or dry, cold or warm, so these qualities had to be the ultimate building stones of the universe, as taught by Aristotle. There is an "up" and "down," an absolute space, as expressed in Euclidian geometry. As to human reasoning, it was thought to lead to more reliable results than crude trial and experiment, as reflected by the dictum of Aristotle, according to which a big stone falls faster than a small one. What is remarkable about this statement is not that it is wrong, but that it never occurred

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to Aristotle to try. He probably would have regarded any such proposition as an insult.

Two thousand years later, in that great awakening of the Western mind called the Renaissance, something new must have happened to the human mind because a boisterous young man, Galileo by name, went up a leaning tower with two stones, a big and a small one, in order to drop them simultaneously, having asked his companions to observe which of the two arrived first on the pavement below. They arrived simultaneously. This same man also doubted the perfection of his senses, built a telescope to improve his eyes, and discovered with it the rings of Saturn and the satellites of Jupiter; a most dramatic discovery because nobody had seen these before, and so they, as well as the whole universe, could not have been created solely for man's pleasure or temptation.

Galileo was but one of the first swallows of an approaching spring. Somewhat earlier, Copernicus had already concluded that it is not absolutely necessary to suppose that it is the sun which rotates around the earth; it may be the other way around: while Johannes Kepler replaced simple observation and reasoning with careful measurement. Somewhat later Antony van Leeuwenhoek, a greengrocer at Delft, in Holland, improved his senses by building a microscope with which he discovered a new world of living creatures, too small to be seen by the naked eye. Thus began the science which I will call "classical," which reached its peak with Sir Isaac Newton, who, with gravitation, made a coherent system of the universe.

This *classical science* replaced divine whim by natural laws, corrected many previous errors, and extended man's world toward both the bigger and smaller dimensions, but introduced nothing new that man could not "understand." By the word "understand," we simply mean that we can correlate the phenomenon in question with some earlier experience of ours. If I tell you that it is gravitation which holds our globe bound to the sun, you will say "I understand," though nobody knows what gravitation is. All the same, you "understand" because you know that it is gravitation which makes apples fall, and you all have seen apples fall before.

For several centuries this classical science had little influence on everyday life or human relations and was merely the intellectual playground of the selected few who wanted to look deeper into Nature's cooking pot.

Around the turn of this century (1896), two mysterious discoveries signified the arrival of a new period, the period of *modern science*. The one was that of Wilhelm Röntgen, who discovered new rays which could penetrate through solid matter. The other was the dis-

covery of radioactivity by Antoine Henri Becquerel, a discovery which shook the solid foundation of our universe, built of indestructible matter.

This modern science disclosed the existence of a whole new world of which man had no inkling before—the world of quanta, elementary and "strange" particles, electronic clouds, atomic nuclei, electromagnetic waves, and the relativity laws of superhuman speeds and dimensions. In a way, this is the real world, and the world we knew before is but a flickering shadow. The atoms of which I am built have been here for millions of years, but their temporary assemblage which is me is but a fleeting one. Not only are our senses unfit to disclose this new world to us; they are made so as not to disclose it. They are made simply to help us to get through the day alive, to find food and safety. If they would show the basic reality they would be useless. If I should see this platform as it really is, a vacuum with here and there an atomic nucleus surrounded by electronic clouds, I would be afraid to stand here, and if I should doubt the existence of an "up" and "down," I would break my neck in no time.

No human experience comes to our help to understand this new world. We have no experience whatsoever in these dimensions, and there is no human language to describe it. Who of you can make any sense of my statement if I tell you that the smallest piece of light (a photon) is both a little ball and a wave, a wave which spreads in all directions as an expanding bubble, its radius growing with a speed of 186 thousand miles a second, but if an eye sees this light at one point, that is, catches the photon, no one else can see it anywhere because the whole sphere collapses? Certainly, it makes no sense to me, but all the same, I have to accept that it is this way for mathematics tells me so—mathematics, which allows me to penetrate into this new world because it is not limited to any dimensions.

Man is a newcomer, a stranger in this new world in which he is not made to live. He has become master of superhuman forces and speeds but, at the same time, carries in his mind his ancestral heritage of rapacity, lust for power, hatred and distrust, and short-range selfishness. He has acquired simultaneously the ability to create undreamed of wealth, happiness, and dignity for everyone as well as the ability to destroy himself and damage his genetic material, guarded by Nature for millions of years. His ancestral heritage pulls him toward the latter. At present we are in a deadly race between education and suicide, with the latter far ahead. To stay alive in this new world, we need entirely new human relations, political structures, and thinking.

Human existence, at present, is balanced on the razor's edge. The conventional sources of energy, like coal or gas, are very limited and

will give out within a century. This would have meant a collapse of our whole civilization. Atomic energy has shied away this specter at the eleventh hour, but, at the same time, it conjured up another: self-extinction. We deal with the new cosmic forces of the atom as if they were the petty forces of the past, being unable to imagine how hell on earth will look, once these forces are turned loose.

I have hitherto talked only about science, neglecting science's twin brother, technology, which was created by the same type of mind, the same cool-headed, objective thinking as science itself. Only the ultimate goals of science and technology are different. Science wants to understand; technology wants to create useful tools.

Technology has had a more profound influence on human history than science. While science has remained, up until a century ago, the intellectual playground of inquisitive minds, the milestones of human ascent were technological advances. The main events of the distant past are not the wars and glory of conquerors but the discovery of the first simple tools, the discovery of the needle and the wheel, the discovery of iron, steel, and copper and its alloys. At the beginning of the last century technology began to bear on politics and almost changed the political history of Europe. As you all know, Robert Fulton, who constructed the first steamship, offered his invention to Napoleon. Had Napoleon listened to Fulton, he would have beaten the British fleet and conquered England, and political history would have taken a different course. We can bless fate that dictators have their limitations, for a similar situation arose under Hitler, who was prevented from developing the atomic bomb only by his contempt for the intellect. The impact of technology and history became more and more decisive. In the first half of the last century, George Stephenson's "iron horse" replaced the live one and started herewith the re-evaluation of distance, which is still going on. Toward the middle of the last century, machines, with the consequent Industrial Revolution, started reshaping our social structures.

Up to the last quarter of the nineteenth century, science and technology had practically nothing to do with one another. Only toward the end of the last century has science begun to spill over into technology by the utilization of electricity and Michael Faraday's dynamo.

The fusion of science and technology seems to be complete in our period of modern science, where technology is almost entirely dependent on the progress of basic knowledge, which makes the future of any leading nation dependent on its progress in basic research.

If I have not talked yet about my own science, biochemistry, biology, and medicine, this was because these sciences are not independent but depend on the general progress of science for their

development. Biochemistry has grown up on the shoulders of classical ideas. The main object of study in chemistry is the molecule, its structure and its reactions, and so the main concern of biochemistry, hitherto, was to disintegrate the living system into molecules, then to identify and study these molecules. So present biochemistry is dominated by what is called "molecular biochemistry." This science has led to the most astounding successes. It led to the isolation of the mysterious hormones, which dominate our development and reactions, most of which you find now as modest powders on the shelf of the biochemist, synthesized in factories. We have isolated and identified the vitamins, which can be synthesized by the ton, while not so long ago their lack caused untold suffering, the deficiency diseases sweeping over countries like the most deadly epidemics.

Biochemistry has penetrated into the structure of proteins, responsible for the most important reactions taking place in our bodies. We have even penetrated into the structure of nucleic acid, which is responsible for the synthesis of proteins and carries in itself the genetic information, the blueprint of our bodies, from generation to generation. One of the latest triumphs is the breaking of this genetic code, which may, in time, enable man to take creation into his own hands, shaping new species with the desired qualities. In a way, such creative work has already reshaped, to a great extent, agriculture. Owing to a concerted effort of chemistry and electron microscopy, we talk about viruses, the smallest and most deadly enemies of man, as of molecular structures which we can see and describe in terms of classical chemistry. We are still far from the end of this glorious march. Research going on in my own laboratory gives me the hope that soon we will have in hand a new hormone which has a dominating influence in that desired state, called youth, which we all would like to see prolonged. This research may also yield up a substance which might enable us to cope with cancer.

However, if we do not allow our eyes to be blinded by these successes we find in their shadow, also, failures—disturbing failures connected with our failure to understand the most basic phenomena of life, by which we know life from death. Since the dawn of mankind, death was recognized by the lack of motion, reflexes, and secretion, or, to put it into a more scientific language, the transduction of chemical energy into mechanic, electric, and osmotic work. We do not understand any of these. If we look deeper into the problems of biology, we will find that the most central problems are almost untouched. What is a cell, this most fundamental unit of life? How did life originate and develop? How do hormones act? What do the lamellar structures of the cell mean?

What has occupied me during the past decades is this question: Why have these most basic problems remained blank spots on our map of knowledge? I have come to the conclusion that in order to approach these problems we must descend from the molecular level into that mysterious domain of modern science which deals with quanta, electronic clouds, and their interactions. I strongly feel that life did not start with molecules. What was there in the beginning was energy, the the quanta, electrons, and atomic nuclei. Life was shaped from these, and, in order to understand the most basic problems of life, biochemistry will have to descend into their mysterious world. I expect the next big forward leap in biology and medicine from the penetration into this domain. This will not only complete our knowledge, but it will also be able to gratify almost all wishes and dreams that man ever had.

We, actually, are already on the way to a carefree, elevated, and dignified form of human life. We do not notice the change because it is gradual, and we are in the middle of it. I want to remind you only of a few simple facts. Today, an unskilled workman in our country has a much more dignified and elevated existence than the mighty princes of the Middle Ages, whose life we could not stand for any length of time. While in the past man's main worry was how to provide the food needed for his maintenance, our main worry today is to keep our waistline within bounds, and our difficulty is less in producing than in storing the food in our bursting silos. We can produce more than we can consume, and one of the important factors behind the present armaments race is the simple fact that we can keep our economy in balance only if we waste a considerable part of our labor and production.

The greatest problem of the future is not how to produce the elementary necessities of life but what to do with all our spare time, how to create beauty and knowledge to lift our existence to undreamed of levels of culture and happiness. What we have already achieved far outstrips the most fantastic dreams of the past. We have eradicated the epidemics, our wives can look forward with quiet happiness to bearing children, and we do not share the feelings of the great composer, Johann Sebastian Bach, who judged himself a most fortunate and blessed man, having been able to keep alive half of his numerous children. It is true that all this is only the privilege of a smaller fraction of mankind, but there is no reason why all this should not become the common property of man and why any human should go sick or hungry.

If I resist the temptation of picturing to you the glorious future which modern biology and medicine promises, this is because the

greatest enemy of man is still unconquered. This is, no more, viruses, bacteria, or hunger, but man himself, his shortsightedness, his narrow partisanship, his hatred and distrust. Man with his ingenuity found means in high-energy radiation to damage his own genetic material which Nature has preserved for him through millions of years with such utmost care. Man has found means to wipe himself off the face of his rapidly shrinking globe at the price of untold suffering. This is no more a medical problem. It is a problem of morality, of the spirit of a wider human brotherhood with a corresponding political structure; and my great desire is that my beloved country, the United States of America, which has shown the way to wealth and the peak of material well-being, should show also the way toward such a new spirit of a wider human community and with it the way to the golden age, which man has dreamed about since his humble origins.

HENRI MAURICE PEYRE

A Frenchman's View of American Education

EDUCATION, until a few years ago, used to be considered an uninspiring subject, especially when treated by professional educators. It lends itself to as many platitudinous strings of dogmatic assertions as any sermon or any politician's speech, without the fervor of the former or the bland cynicism of the latter. It seldom encounters worthy opponents, since there are in this country even fewer persons openly aligning themselves against education than there are blatantly favoring sin. In truth, the people whom it would be most worth our while to hear assessing their education are the Seniors just graduating from college or the men and women who would examine the education they received twenty or twenty-five years earlier, when the results could appear most beneficent, or else to have been futile. But mature men of affairs and women without affairs are seldom anxious to look back upon their eager, idealistic, and naïve selves of a quarter of a century ago. Seniors are too happy to submit to a baccalaureate sermon and to one or more commencement addresses as their initiation rite to their lives of already educated men: they seldom criticize or appraise. The task devolves upon professors.

The present one happens to be a Frenchman who came to America in his early twenties, seduced by the adventure of teaching abroad, and of teaching young women; he has since taught elsewhere but has returned to America, convinced that he could serve the future of mankind, if such an absurdly ambitious purpose may be permissible to a youth, more fully and more freely here than in Europe. He has long become identified with American higher institutions of learning and professional societies, so that much of the aboriginal Frenchman in him may have evaporated. His advantage lies perhaps in his ability

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to see American education both from the outside and from the inside. His strictures are addressed to himself first of all. He does not claim to stand on a lofty peak with centuries of experience behind him or under him and to talk patronizingly to a country devoted to the tradition of the new. He is ready to proclaim that America, long a receiver in the realm of educational exchange, has today become the giver. The new universities mushrooming in the oldest lands of Europe as well as in the emerging countries of other continents are at present borrowing much from the United States. Many foreigners are readier than the Americans, seldom boastful of their educational achievement, to proclaim that the United States, in its best colleges and universities, has accomplished as much in the field of the humanities as in science, technology, and the social sciences: creativeness in literature, painting, and sculpture; originality in literary criticism, in the study of the classics, of philosophy, and of modern languages—all easily sustain the comparison with any land of western Europe today.

Americans, however, have long ceased to expect from visitors to their shores nothing but fulsome praise. Behind the ritual question, "How do you like things over here?" there lurks much self-doubt. The humility of Americans, even in the Lone Star State, should be a tempting subject for an essayist. As we are gathered in Houston to celebrate a quinquagenarian institution and to map out another half-century of progress, we cannot help wondering how our present achievement will appear to our successors in 2012: puny, ludicrously old-fashioned, fragmentary, brittle. The tragic flaw in any conviction that progress is inevitable and fast accelerating around us lies in the insecurity and frailty of the present viewed as a mere transition stage to something blessed with more greatness or cursed with more bigness.

Let it be said at the outset that nowhere in western Europe (unless it be in a Russia forcibly and ruthlessly concentrating two centuries of growth into three revolutionary decades) has the achievement in the realm of education been more striking, since 1912, than in the United States. This country attempted to educate every child for democracy, while elsewhere it was long considered that college education was a privilege for the few and the gifted and that, since some fortunate young men will fall heirs to fortune and the responsibilities it entails, they might just as well be submitted to some education. What is more, this country, like none other, was receiving in the early years of this century a large influx of immigrants from Europe whose children had not enjoyed any cultural benefits and who were uprooted from the folk traditions and from the wisdom which it is often the lot of grandparents to impart to the young while

the parents are at work in the fields or in the factories. None of the common background and uniformity of goals which did much for secondary education in western Europe was to be found among the heterogeneous mass of children—of Italian, Slavic, Irish, Jewish, and Negro stock—which the cities of this country had to train in their schools. At that very time the power of religion to supplement lay instruction with notions of ethics and of duties to a spiritual creed also happened to be weakening. Teachers colleges and social disciplines had to step in and try to fill the vacuum. If they appear to many fastidious minds to have fallen short of their ambitious claims, it must be borne in mind that the traditional colleges, in those years, took scant heed of the needs of the schools and of providing teachers for the most motley crowd of children ever to be found in any land.

Education at the elementary- and high-school level will be left out of this essay: it behooves those who have gone through those schools or have had children in them or served devotedly on their boards to address themselves to the subject with competence. The best of the American colleges and universities (the latter is a word very confusedly used in this country and often brandished by minor institutions) easily rank among the score of best universities in the world: they provide examples for the reformers now fast at work in altering the face of the Common Market countries and of Japan. To be imitated and envied, however, is a perilous lot. It challenges the institutions which have progressed swiftly and well to attempt even more. It should act as a spur to self-criticism. Happily, of all professions that of education is the one which welcomes, and utters, criticism most willingly. Most men who once studied Latin, French, arithmetic, or even English grammar at school do not fail to blame, not themselves, but the poor quality of their teachers, for their having subsequently murdered the King's English, French pronunciation, and their figuring, and for having to resort to secretaries to spell or to translate for them. "We were never so lacking in divine discontent," declared Adlai Stevenson in an address in 1961. But presidential discontent is an old American tradition, and every head of a department is ever eager to proclaim that if all is for the best in his institution, loyally praised as second to none, the unmitigated evil of scarcity of funds afflicts each of their provinces separately.

Exactly sixty years ago, as he gave his inaugural address as president of Princeton University, Woodrow Wilson bitterly denounced the low estate of education in this country. Seven years later, in an address to the Phi Beta Kappa chapter of Cambridge on July 1, 1909, he again remarked: "We have fallen of late into a deep discontent with the college, with the life and the work of the undergraduates

in our universities." More recently, Robert M. Hutchins, in "A Speech in Frankfurt" delivered in 1948 to a defeated country, eschewed the arrogance of victors:

> Things have been relatively easy in America. In the management of our internal affairs, we have not had to resort to violence. We have not had to be mean; we could afford to be kind. As to education, I have often thought that, contrary to the impression that prevails in some foreign quarters, America has become rich and powerful in spite of, and not because of, her educational system. Only a rich and powerful country could survive so wasteful and incoherent a system as ours.

Later still, in his volume on *The Conflict in Education in a Democratic Society*, published in 1953, he bluntly and sarcastically formulated the postulate on which American education rests in these terms: "Everybody has a right to education. But only a few are qualified for a good education. Those who are not qualified for a good education must therefore be given a poor education."

The past and the present presidents of Harvard University have expressed themselves outspokenly on the faults both of secondary education and of several features of higher education, even around the sacred "Yard." The president of Yale has been no less vehement, and he attempted to persuade smooth Eli's to give up the prospects of a career in Wall Street or in that more recent devil's alley, Madison Avenue, and prepare themselves to teach in the schools of the country. The launching of the Sputnik in 1957 and the serious technological challenge then brandished to an America which thought of itself as supreme in technology aroused politicians. Congress apportioned funds lavishly. A few scientists were wined and dined at the White House and perhaps even played golf with the President. The country then agreed that if wars, as Lord Attlee put it, begin in the minds of men, as peace also should do, drastic reforms were imperative in the schools of America. Time is of the essence, in this age of acceleration of history. "We are all engaged in a race between education and catastrophe," H. G. Wells had pronounced in a shrewd anticipatory phrase.

The first challenge to be met is one of sheer numbers. In 1900, one out of ten children of high-school age went to school. Today, more than eight out of ten actually are in high school. Of those who finish school, over 50 per cent enter college. There are at present over four and a half million students in colleges and universities, including those who attend evening courses; twelve million approximately in secondary schools. If only college presidents had utilized the powerful lever at their disposal in the form of admissions to

higher institutions and reached a meeting of minds on what their boards of admission might suggest or require, instead of letting individualism and free competition border on chaos, secondary instruction in the United States might have undertaken impressive reforms. But standardization in several realms is in truth repellent to this federal republic; American education is the least standardized of any great country.

Then the amount of things to be learned is immensely more bulky than in the past, even the recent past of a bare forty years ago. Modern men are supposed to acquire rudiments of sociology, anthropology, economics, nuclear physics, synthetic chemistry, genetics, and art history. Where Latin, perhaps one modern language, and occasionally Greek were offered to their grandfathers, today's pupils are confronted with Slavic languages, South American areas, the non-Western cultures, and Asiatic philosophies or views of life as radically different as Chinese and Indian. Strong stomachs are required to digest as much. Far more hours and years should be devoted to that plentiful and bewilderingly varied learning than in the past. But the temptation of jobs awaits the young, added to that of early marriage and of young paternity as a status-seeking and security-granting symbol. Even though half the graduates in many colleges eventually enter a graduate or a professional school, those combined seven years of advanced study hardly represent more than one-tenth of modern men's lives reckoned at three score years and ten. Four years' advanced education in the last century with far less to learn corresponded to one-twelfth of man's life expectancy.

Learning should be multiplied and quickened by imagination. Liberal education in the past was by definition that of a free man who had time for his own cultivation and presumably had slaves or servants. The managerial class today and many educated women harassed by chauffeuring and gardening lack that free time. But leisure and what to do with it is a problem for the many, who work between 2,000 and 2,500 hours per year as compared to 4,500 a century ago. Modern man also has to face a longer span of life, more years of retirement, and yearly vacations. Part of that leisure should be made fruitful through the seeds planted early in life through education. Work motivation in an industrial civilization has tended to lessen for all but the managers and organizers; the meaningfulness necessary to life must come from other sources, which should flow from one's education.

The greatly increased facility of communications has raised as many difficulties as it has solved. The ease with which we travel is harmful to concentration of the spirit. Mass media may serve, and

often do, the stimulating exchange of ideas; but they also unleash "monstrous regiments of words," as an Englishman has called them, and they stifle all clarity of thought. Scientists calculate with awe how high the files of learned journals are going to ascend; they wonder where man will take refuge from too much printed matter. No papers over four years in print, they tell us, seem to hold any value for young science students, at our vertiginous rate of acceleration. After forty, a scientist is resigned to having forsaken his youthful inventiveness, and he abdicates to those younger than he.

The aloneness of modern man is as pathetic in the intellectual realm, where two men of the same branch hardly can understand each other, as it is in emotional and sentimental terms. The weakening of religious shackles has lifted many bans on our behavior—social, personal, and sexual. The general acceptance of Freudian terminology has lent a color of scientific respectability to many freakish assertions of the right of everyone to dispose of his or her body at will. But the fulfilment which might come from the unreserved gift of one's self seldom follows as a consequence. More and better education, more imaginative and vicarious experience due to the reading of literature, more pondering on the wisdom of the past at its best might prevent some woes into which modern men and women rush headlong, through naïveté. Men who had sinned and repented, like St. Augustine, had warned us that love is spiritual even in the flesh and carnal even in the spirit. If the truly educated man is he who gets more out of life than the uneducated, it is questionable whether either the pleasures of the flesh or the joys of the spirit are more keenly relished by modern men and women than they were in ages where hurdles added mystery and zest to living.

A number of trends have recently characterized American education: they stemmed from noble beliefs and excellent intentions; they testified to the optimism of a country which had always dreamed of a new man being reborn away from wearied continents. Their results proved, at least for a time, beneficent. But almost any educational reform, not unlike many medical drugs, after having worked for good, suffers from the wear and tear of years; it is applied with less fervor and more mechanically, and its drawbacks, unperceived at first, loom like grievous faults.

Such was the trend, most conspicuous in the early decades of our century, which pointed to a smooth adaptation to society as the goal of education in a democracy. Too many feuds and wars, in Europe, had been caused by the arrogance of a few, the stubbornness of men devoid of civic devotion, the *hubris* of the gifted, and the scorn of man. A harmonious adaptation to our fellow beings was a

welcome purpose. To this very day the faith of an American in man, concretely envisaged, and his freedom from the distrust and from the aloofness which are rife in older countries, may well constitute, in the eyes of a Frenchman, the greatest virtue of life in the United States.

But the adjustment conception of education corresponded to a belated Victorian era of belief in the perfectibility of man and to an "Age of Confidence." Henry S. Canby conjured up the picture of that age, in which he had grown up, in a book published in 1934, in the middle of the Depression years. Confidence had by then been dealt harsh blows by the First World War and its aftermath, by the Greek tragedy of the Depression, and by the realization that evil could not be easily eradicated through education and the smooth nurturing of "a well-rounded man." Freudianism convinced many people that too much could not be asked from the superego in its wrestling with a sinister "id." A great many of the urges and motives which control or upset an adult's life lay in his unconscious and could, at best, be released and reoriented. C. G. Jung soon after convinced those who had just learned how to assimilate Freud that they were the inheritors, perhaps the victims, of millenary myths and ancestral archetypes and that the past of a race or of mankind cannot be lightly shaken off.

Early nineteenth-century society, in any case, was not perfect, and to be adapted to it was an achievement of dubious value for young men whose task might be not to accept the world meekly but, as for Hamlet lamenting his cursed spite, "to set it right." The inhabitants of the New World had not ascended a plateau on which, like complacent mandarins, they could then bask in secure enjoyment. Good fellowship sounded hypocritical in a society addicted to fierce competition. The well-rounded boy, groomed for social life in a narrow circle, found himself ludicrously ill-prepared to confront the world of the thirties; he understood neither the threat of Hitler nor that of Russia; he tried to close his eyes to his unavoidable involvement in the Second World War. He fought courageously when he had to. But his confidence was shaken forever.

The title given by W. H. Auden to his "baroque eclogue," *The Age of Anxiety,* was inscribed on the banner of the American youth after 1940. The fond assumption of the nineteenth century that democracy would spread to the countries of Europe, Asia, and South America along with the steam engine and the airplane, with central heating, refrigeration, and technological welfare, was sadly belied. The world of our mid-century seemed rather a fit abode for dictators or "providential men"; the American presidential system, per-

haps workable nowhere else, was more often borrowed than American self-government or the spirit of compromise underlying the party system of this country. The American man of 1940–45 found himself faced with what Reinhold Niebuhr had called "the irony of American history": bombing civilians, burning cities during the war, unleashing the first atomic bombs, all as lesser evils or means toward a dubious good.

The American man of the sixties cannot help but realize that, while worshiping at home at the altar of free enterprise and demonstrating the success of capitalism, he and his country can only assist socialism abroad through distributing, via state channels, in Korea, Laos, Egypt, and the African nations, the funds which he is persuaded he must vote for. All of a sudden, the stress came to be put, in education, on the gifted or the superior child, not on the retarded one; educators, presidents, and lecturers were never more heartily applauded than when they argued the need for "creative heretics" (Arnold Toynbee's phrase in a Bryn Mawr address) and against the new bugbear of college life, conformity.

Specialization appeared as the unavoidable rule for education and learning in a world in which there was far too much to learn in too little time. Was it, however, as unavoidable as it appeared to those who were overly impressed with the division of labor practiced in factories and offices, even in medicine and psychology? Auguste Comte had prophetically warned his contemporaries, more than a century ago, that they would have to evolve specialists of generalities linking the multiplying disciplines, all too divergent. Too much has been repeated about the "two cultures" lately, and with scant profit. For communication is even less to be found among scientists themselves, even among diverse categories of physicists or of biologists, than between scientists and literary scholars. And it often ceases completely to link scientists twenty-five or thirty years old and those who, a quarter of a century their seniors, have long ago given up understanding the young and have taken refuge in administration, in fund-raising, in history of the science which they fear they can no longer advance, or in philosophizing about the laws of thermodynamics, the principle of indeterminacy, or the reconciliation between science and religion.

Humanists are even more to blame. For they erect structures of concepts, perhaps of words, if they are philosophers, without keeping abreast of the insight into phenomena provided by recent science. They reason obstinately about meaning and language, but they hardly enrich the philosophical sensibility of the laymen. They seldom bring their study of the past to bear upon the present; and historians be-

tween the two world wars, in America, in England at All Souls and at Chatham House, and probably elsewhere too, proved the most obtuse of men in the presence of the German menace and the most obdurate champions of noninvolvement in a war which was, from the outset, to be America's war and to make America aware of her immense power.

Through a certain complacency and sulking at their fall from their earlier high estate, many humanists have allowed the social sciences to break away from the humanities altogether and to lose thereby far more than they have gained. In this author's opinion, no separation is more gratuitous and artificial and more harmful in American universities than that which divides the social sciences (the French prefer to call them *sciences humaines*) and the humanities. How unnecessary those cleavages are is shown by the fact that many editors, publishers, college presidents, and executives refuse to be specialists and see men, events, and knowledge "steadily and see them whole." Decision-making has come to arouse paralyzing fears in many moderns because they have been accustomed to contemplating only a very narrow province and never to communicating beyond those artificially erected boundaries. Yet Henri Bergson and, more lately, Sir Julian Huxley have pointed out that the animal (the ant, the bee, or the beaver) is the ideal specialist and that there is little ground for man's descending to the status of a well-adapted, tightly specialized animal. "Specialization—in other words, one-sided adaptation to a particular mode of life—eventually leads to an evolutionary dead end," declared the British biologist in *New Bottles for New Wine*.

A serious fault of our universities is the ludicrously scant use made of the presence of many cultured men together to foster the exchange of ideas. We fail to multiply the old by the young, one man by another, and man by woman. Sixty or more years of development of advanced education for women in this country should have brought about more of an enrichment of one sex by another. In contrast, the two halves of mankind, into which Plato's androgynes were severed, educated under the same teachers, seem to drift apart in mature life more than they ever did.

The obsession with the quantitative appears to an outside observer of American education as the other flaw in the unwieldy and gigantic structure erected to train the young. It also originates in a justified desire to distrust mere impressionism, looseness of thinking, vagueness of judgment, and shoddy approximations. Measurements had enabled the sciences to attain exactness and rigor. The social sciences endeavored also to surround themselves with precise data and to evolve statistical averages, even laws of a kind. The challenge of numbers was

pressing; examinations could not be pondered over by leisurely judges; criteria on what constitutes a good style in English or a tolerable translation or a keen insight into history are variable and fallible, once traditions and the established taste of an elite class have begun to be questioned.

The temptation was strong to resort to machines for grading, to either-or questions, to summary devices for measuring the I.Q. of young people—yet there are so many ways of being intelligent! And there is much to be said for the slow and perhaps deeper minds which fail to react to tests with the speed and slickness of the faster ones. There is even more to be said, and it seldom is said today, for those young students who are none too adept at solving the problems prepared by their teachers according to time-honored traditions or routines, but who perceive new problems by themselves and put those up to their instructors. Yet our entrance boards do not as a rule favor those independents and rebels. Far too few of the most original scientists of America, fewer still of the writers of talent, have been coming out of the universities of the East Coast which once produced them or did not succeed in dampening their eagerness. Neither our system of examinations nor our seminars with their enormous amount of wasted motion and of futile discussion under a veneer of cordiality satisfy many of us nowadays. The study of literature is especially deficient, since it seldom instils taste, independence of judgment, and prolonged desire to read in mature life, as it should.

Yet today as much as yesterday if not more, most of the decisions we make in life are made intuitively, through jumping to conclusions and venturing rash value-judgments. Speculation and even gambling are not the monopoly of the financiers; statesmen, military men, high executives, and philosophers also proceed in ways seldom reducible to logic, once they have made a careful survey of all the facts available. The facts are never all there in complex human affairs. The fascination which quantitative criteria hold for many young minds tends to deprive them of common sense and of imagination. Clarence B. Randall (himself an industrialist of no mean standing), in a volume entitled *Freedom's Faith*, denounced in 1953 the grave flaws of technical education: "It leaves in the mind of the student the impression that all problems are quantitative, and that a solution will appear as soon as all the facts have been collected and the correct mathematical formula evolved. Would life were that simple!"

Even among those Americans who were trained in liberal-arts colleges and should have developed, through history, literature, and the languages, a sharper sense for nuances and for all that is qualitative, a lack of subtlety and of flexibility has been obvious of late, and is all

the more deplorable as this country stood in need of an army of educated citizens able to face the unforeseen and to deal with the unpredictable foreigners. Every other man alive today is an Asiatic; every fourth or fifth man is a Chinese; Christians are a small minority in the world; and Western nations are a minority in the United Nations. The chances are more than even that every educated American will have to transact business (mercantile, governmental, diplomatic, intellectual) with very strange people, unimpressed by Anglo-Saxon traditions, if they ever heard of them. The training in business schools or in law schools, beneficial as it may be to develop analytical and trenchant minds, is not the best calculated to produce the sort of envoys or representatives that this country needs. A British veteran from the foreign service, Sir Harold Nicolson, warned us long ago that "the worst kind of diplomatists are missionaries, fanatics and lawyers." Those men believe in sharp differences between right and wrong. The lawyers know how to forget about that difference when they help their American clients with their charge accounts or their depletion allowances. But they are naïvely surprised when they discover that foreseeing every contingency, closing every loophole in a negotiation with an Asiatic, a Latin, or a Slav, drawing a neat line between legality and illegality in international relations only bring frustrations and deceptions in their wake.

Most of life is closer to an art than to a science; most problems are not of logistics or of legality, even less of statistical percentages, but of personal relations and of nuances. More than ever before, this country needs men who have long practiced literature and the arts and have learned thereby that no fixed standards of any kind enable any of us to discern what is beautiful, deep, sincere, great. Personal relations, emotive values, qualitative differences lie at the source of most policy decisions. A politician who ignores it soon meets his doom. President Kennedy, one year after he had taken office, confessed to a reporter who questioned him on his biggest and most disappointing surprise in the exercise of power that he had been most amazed by the relative inability of the United States to influence the policies of other nations, allies included. It is the function of colleges, in the mid-century which is clearly the age of American guidance for a good part of the world, to provide the country with citizens who will have not only specialized technical ability but also resiliency, flexibility, the imagination to devise alternative solutions, and, as Talleyrand's famous requirement for a statesman put it, "future in their souls."

The three main factors defined above (adaptation to society, specialization, reliance on quantitative criteria) are those which a French-

man, or any foreigner, believes to have been overstressed to the point of working more harm than good, but they are not naturally specific weaknesses of American education. It merely happens that they have been driven to excess faster in the United States than in Europe. But European nations are embarked on the same road and are likely to suffer from the same evils as they, too, place education within the reach of all and find themselves resolutely in the midst of technological age and civilization. As always, the bitterest strictures of America by Europeans are in reality directed at themselves, and at what they fear is the unavoidable future in store for their own countries. Alexis de Tocqueville was similarly fascinated and horrified by the prospect of American equalitarianism spreading to Europe; but he was too sedate a magistrate ever to indulge in vituperation.

A foreign observer of American education is aware of enough excellence and more than enough good will among his American colleagues to leap beyond the barriers of good taste and of wisdom and imitate the masochistic breast-beating which has tempted many native writers in education ever since the first Sputnik and the first Russian space satellite. His ambition is to assist western Europe in eschewing some of the excesses to which some trends in American education have been driven and, through his half-foreign and thus more independent point of view, to participate in the reappraisal now being accomplished in the United States. Denouncing faults without suggesting remedies is both too easy and too vain a pursuit.

Partly as a consequence of a misplaced worship of facts as such, on the part of the specialists and quantity- and figure-loving researchers whom we have turned out of our colleges in the last half-century, partly because the overabundance of information ends by confusing the overinformed, the most grievous flaw in our civilization is now passiveness. Our much advertised angry young men have not long stayed angry, nor has their sonorous wrath been directed at genuine evils. A glance at the titles and the covers of many of the paperback novels displayed in drugstores and hotels is enough to send a shudder down the spines of visitors to this country: Have women sunk that low in the estimation of readers, has love been degraded to such a degenerate squalor? We know that the answer is "No," from the many normal, moral, generous friends we have. But our image of ourselves is not flattering. On another level, the scandals which have been revealed in the press over the last decade (involving a president of Chrysler Corporation, twenty-nine high officials of General Electric, New York Stock Exchange leaders, contractors and builders, sugar lobbyists around Congress, pharmaceutical-products manufacturers, financiers escaping to Brazil, or flamboyant Texans, Ixion-like, embracing clouds and offering them for sale) should have revolted the

electors and spurred the youth to reforming zeal. The scandals of a similar order of magnitude, and even more placidly condoned, which exposed several labor unions to what should have been the contempt of working classes have been tolerated with just as much leniency. Other countries have had their scandals and their venal press, to be sure; but the American scale is apt to be larger, and the greed for a fast profit is uncontrolled by a too apathetic public opinion.

The danger, in our eyes, is more serious than any external peril such as that of communism—so serious that, were a recession to strike as in 1929, the more thoughtful portion of the youth in this country might well, as idealistically and perhaps as mistakenly as in the thirties, be intellectually alienated from the bulk of American civilization and revolt against free enterprise as they have seen it abused by some greedy tycoons. The blame should be laid at the door of the press, of the mass media of all kinds, but ultimately on the lap of those whose function it is to educate the country. We have not endeavored hard enough to impart a critical spirit to our pupils. We have accumulated unrelated facts for them, but taken less pains over the far more essential evaluation of the facts.

The time-honored civilization of the printed word, we are warned, is today yielding to the civilization of the mobile image. Numbers may force schools and colleges to replace lessons and lectures by a television screen, and the potentialities of the new medium are certainly boundless; only timid traditionalists will sneer at them. But as the cult of images spreads among us, so should the fostering of the power of attention and of the ability to reflect, or else we shall listlessly watch images change into other images just as "thin and strange" as the preceding ones, at the very moment when they might have been metamorphosed into thought. The children of our day, who are to live with the mass media and cherish Walt Disney and the TV screens, need, far more than in the past, to be armed against passiveness and to resist the slumber of the spirit. The decline of attention, as it has been called, is today an insidious enterprise against our intellectual power of distrust; it is conducted by all those who wish to wash our brains, to dull our sales resistance, to suspend our disbelief forcibly so that we shall meekly absorb many products which we hardly need or want, but are told with obstinate repetitiousness that we should somehow want.

Even worse than nuclear bombs, the poisoning of men's minds through publicity taken over by government agencies and authoritarian tyrants has been the most tragic catastrophe of our age. America distrusts tyrants, government agencies, and official publicity. But it takes more than the custom of printing in our magazines four reader's letters for and four against a controversial article to develop a criti-

cal spirit and a personal opinion in readers. Impartiality, when thus banalized, leads to moral indifference. The Korean War and the lamentable lack of critical sense displayed by many Americans taken prisoners by the Chinese in 1950–51 should have served as a warning to those who should have educated those men better. In a book entitled *In Every War but One* (only the Civil War had recorded more casualties among prisoners), Eugene Kinkead related the stupid conduct of one out of three Americans taken prisoners, who agreed to collaborate with the enemy, and the sad fate of 38 per cent of the American captives who literally allowed themselves to die in captivity, while Turkish, Greek, and other prisoners closed their ears to Chinese propaganda and survived. The incident is a lamentable reflection on the gullibility and proneness to demoralization in men who presumably had been through the schools and the colleges of this country.

A Frenchman who has retained his full confidence in the youth of this country may be entitled to say that the older generation is in part responsible for the evils which it now laments. Many delinquent youths might have turned a different way if their parents had inspired them with greater respect; instead of which, the parents have, in order to appear perennially young themselves, played up to the whims of their adolescent children, abdicated their role as intellectual and moral guides of the young, and incurred their secret contempt. Teachers are just as guilty, for they lack the competence or the energy to stimulate their pupils when those are at a receptive age; too often, they were not recruited from the best in college classes; their profession is not glamorous enough; it is too poorly rewarded; it does not provide them with enough incentives for further intellectual growth. A great modern country should select its very best men and women, as is attempted in several competitive *grandes écoles* in Europe, to exercise the most difficult of professions, and potentially the most influential: that of training its future citizens. As Freshmen get to be selected more and more severely and are presumably brighter and brighter, they are in danger of being as good as their instructors, if not more alert mentally. Disrespect naturally ensues.

The once much-vaunted self-reliance of Americans has given way to self-doubt. Psychoanalysis, the teaching of history as futile and confusing, replacing the earlier sanguine conviction that its course was a march toward liberty and progress, the severance of much philosophy and of law from any moral content, the sordidness of much literature since 1920 have spread bewilderment and apathy in some groups of Americans. They bask in the plays of the absurd, in squalid novels about college life reduced to casual sex adventures and with no mention whatever of intellectual excitement, and they adopt as an

adequate portrayal of their own the weaknesses depicted in T. S. Eliot's early satires:

> Shall I part my hair behind?
> Do I dare to eat a peach?

or the view of history entertained in "Gerontion," with contrived corridors and whispering confusion, in which "unnatural vices are fathered by our heroism, virtues are forced upon us by our impudent crimes."

Yet those cynics are the exception, and he who knows the young Americans of today cherishes valid reasons for hope. The urge for commitment to a great cause is powerful in many of them, if misdirected or baffled. For the first time perhaps in the history of the world, they stand ready to assist other nations, to devote themselves to these countries which have not enjoyed the same privileges as they have. A planetary consciousness is slowly dawning. Many are those who realize that time is of the essence and that young nations, in Africa, Asia, or in the Caribbean, suddenly emerging from a state of underdevelopment, perhaps of barbarism, short of equipment and of wisdom, are ready for evil as well as for good, for violence as well as for peaceful co-operation. Two-thirds of the world's population are underfed; 8 per cent of the world's annual output is being spent on armaments, which amounts to more than half the income of the underdeveloped countries. Military expenditures in a decade of peace have, between 1952 and 1962, far outstripped all that mankind has spent on education for two hundred years.[1] If those who should be the intellectual leaders of the civilized countries placidly accede to the present inevitable drifting to warfare and wholesale destruction, they will be accountable to whatever survives them. In the very broad and nonpartisan sense of the word, educators must today assume again their political role and prepare young men and women for the most challenging demands ever made upon one generation. Woodrow Wilson's words, pronounced as early as 1906 at Cleveland before the Western Association of Princeton Clubs, have acquired even more relevance today than they had when the century was young and America relatively isolated: "I do not see how any man can fail to perceive that education, in a country like ours, is a branch of statesmanship. It is a branch of that general work of enabling a great country to use its energies to the best advantage and to lift itself from generation to generation through stages of unbroken progress."

The need for educators, with the help of families, of alumni, of statesmen, of journalists and authors, and of business leaders (who

[1] See Surendra J. Patel, "Economic Consequences of Disarmament," *Bulletin of the Atomic Scientists*, XVIII (November, 1962), p. 9.

know better than any other group of citizens that, while we tap underwater oil and uranium deposits, we do not endeavor to find and to develop men with the same energy)[2] is to redefine today the goals of American education. We have too long dwelled on social sophistication, rubbing off the edges of our graduates, lauded the benefits of going to college to make the right connections and mate eugenically. Those were worthwhile, or enticing, values in an age of confidence and security, as aristocratic values were fitting for eighteenth-century men of leisure in France during the age of *la douceur de vivre*. But the scaffold, revolutionary wars, and the unleashing of new forces of passion pounced upon those who had dreamed of eternally sailing toward Cytherea. Their successors had to piece together again the fragments of a broken world. They accomplished a splendid task in the nineteenth century with the same audacity as men of the Renaissance, watching the crumbling of an old order three centuries earlier.

There is no reason why the men of the American half-century, from whom the rest of the world expects much, should not do likewise. The goal of advanced education is no different if it is to be pursued by the many and no longer by a few: to turn out men who can think as men of action and act as men of thought. But it can only be pursued successfully if those entrusted with youth cease nursing its childish psyche, leaning over every adolescent as if he were to be pitied and looking upon him as a network of problems, and become determined to regard youth and adolescence as a stage leading to manhood and womanhood and a preparation for the responsibilities pertaining to maturity. We have in the last few decades stunted the growth of those whom it was our duty to help grow to a firm clarity of purpose. They have not been persuaded by society or by educators to compete with the best that they might be, instead of specializing narrowly and accumulating data and technical "know-how." Yet intelligence aroused by imagination remains the primary need in this country, whose destiny it now manifestly is to lead half of the world or more. Emmet John Hughes, a man who observed public affairs and America's foreign-policy–makers closely (in his book *America the Vincible* [New York, 1959]), may be paraphrased: No affluence of wealth can for long hide a failure of intelligence. No affluence of wealth can for long hide a failure of brain.

[2] Again Clarence B. Randall may be quoted, with the authority which accrues in America to a leader of the business world: ". . . What are we doing to locate a Lincoln, a Woodrow Wilson, or a Churchill to inspire and guide each new generation? We have learned how to drill a mile under the surface of the earth and bring hidden treasures, but what are we doing to pierce the depths of the human heart and lay bare its secrets? This is the blind spot in business today. We have mastered machines but failed to understand men" (*Freedom's Faith* [Boston, 1953], p. 61).

CLAUDE ELWOOD SHANNON

Computers and Automation—Progress and Promise in the Twentieth Century

THE TECHNOLOGICAL PROGRESS of mankind in exploiting its environment may be divided into three main streams of activity. The first and earliest of these relates to exploiting material resources. Man learns to use wood for shelter, develops agriculture for food and the use of metals for tools. In our time this has led to the great industries relating to extraction, manufacturing, and transportation.

The second major stream of activity relates to the exploitation of our energy resources. Early man uses fire for heat, domestic animals supply transportation, and he harnesses both wind and water. The development of the steam engine and the internal combustion engine were important break-throughs in this area, followed by the wonders of electric-power engineering. A most important point in this history was the first industrial revolution, when it became clear that it was possible to replace man's muscle by the power of a steam engine, using a man only to control this energy. Our own century has seen further break-throughs in the exploitation of energy, the use of nuclear power and the promise of solar energy. The rapidity of change on this scientific front can be judged from the fact that while atomic energy is only twenty years old, power engineers tell me that steam-driven generators are now almost obsolete.

The third great stream of technological activity relates to the collection, transmission, and processing of information. Early man learned to communicate with his fellow man by the spoken word and later to use writing and a printed book to record and disseminate knowledge. The great and explosive growth in communication and processing of information, however, occurred in the late nineteenth

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century and in the present century, spurred by the development of electrical technologies. In rapid sequence we had the various powerful communication media—the telegraph, the telephone, radio, and television, together with the information-processing devices of computing machines, control systems, and the like. It is this area of information-processing and communication that I wish to discuss today.

Information, like many other words, has both a popular and a technical meaning. In the popular sense, information is what we find in a book or hear when someone is speaking. Technically, information relates to choosing one possibility from a set or ensemble of various possibilities. The information in a sequence corresponds to the fact that it is this particular sentence chosen from the set of possible sentences. Information is always carried either by means of matter or energy. In the case of a book, it is carried on a material carrier; in a radio wave, on a medium of pure energy. The information, however, is not the underlying carrier but rather corresponds to the particular form or pattern impressed on this carrier as one from the set of possible forms it might assume.

The relations between information, energy, and matter may be illustrated by a little anecdote involving Samuel Johnson. His biographer, James Boswell, tells us that at one time Bishop George Berkeley proposed a philosophy of idealism, suggesting that the real world about us was not, in fact, real, but only ideas in one's mind. When Johnson was asked how he would refute this philosophy the good doctor said, "I would refute it thus," and took a mighty kick at a nearby stone. I don't wish to take a position on idealism versus realism but would like to point out the parts played in this little story by matter, energy, and information. Matter is represented by a stone that Johnson kicked, energy by the muscle power he used to kick it, and information by the thoughts and nerve currents which caused his muscles to so act. The three entities are playing parts here which are entirely typical. Information controls energy which then acts on matter.

In its technical sense, information can be measured much as we measure energy or mass. The unit of information is the bit. It corresponds to the information produced when a choice is made from two equally likely possibilities. If I toss a coin and tell you that it came down heads, I am giving you one bit of information about this event. More complex choices correspond to larger numbers of bits. The unit of information is useful in measuring storage capacity in computers. For example, one might have a computer with a million bits of storage. This means that it can store a million independent yes-or-no decisions.

Again, the measure is useful in communication problems where one is concerned with how much information is produced by an information source and how much capacity may be available in a communication channel. If the capacity of the channel, in bits per second, is less than the rate of production for the source, it is impossible to transmit all the information over the channel. On the other hand, if a greater capacity is available than the source rate, it is possible by suitable coding to transmit the information with substantially no errors.

It may be noted that the unit of information says nothing whatever concerning the value or importance of the information. The outcome of a presidential election still corresponds to only one bit if the two candidates are equally likely to win and less if the probabilities are biased. It is analogous to the fact that a gram is the same whether it be a gram of diamonds or a gram of sand.

In the first industrial revolution we have said that man's muscles were replaced by external energy sources. We are now in the midst of what Norbert Weiner has called the second industrial revolution, in which man's control function is replaced by computing devices. This actually started long ago. The Jacquard loom, for example, used a rather sophisticated control system based on punched cards for controlling the harnesses of a power loom. However, automation, like communication, really required the speed and simplicity of electronics for adequate realization.

Automation in this century was initiated on a large scale with the development of the dial system for telephone switching. This was not only efficient and desirable—it was, in fact, absolutely necessary. The present level of telephone traffic, if handled manually, would require the services of almost all the young ladies of suitable age in the country. The telephone-switching system uses electromagnetic relays, a rather slow type of component operating in the millisecond range. The most exciting possibilities in automation and computers stem from the vacuum tube and recently the transistor, those two wonderful devices capable of operating in fractions of a millionth of a second. These can be used for many types of logical operations required in processing and transmitting information.

The development of the transistor was a genuine scientific breakthrough of absolutely first-rate importance. I recall some fifteen years ago when I first saw a transistor and was completely taken with the beauty of its tiny size and small power requirements. It seemed an absolutely ideal component apart from technical difficulties with noise levels and reliability. In the intervening fifteen years our ideas have changed. We now regard the transistor as an easily manageable device but rather large and bulky. Most of it, after all, was empty air, and

now we are looking to microminiaturization which reduces size again about as much as the transistor did relative to the vacuum tube.

This highlights an interesting feature of information-processing devices. Information can be carried on almost arbitrarily small bits of matter or of energy. It would seem that the only limits are set by difficulties of manufacture as a practical limit and the presence of thermal noise or quantum uncertainty as a theoretical limit. Nature, however, is still far ahead of us in the miniaturization game. This may be illustrated by a simple calculation. If we regard a neuron in the brain as about the equivalent of a vacuum tube and if we were to build an electronic circuit with as many vacuum tubes as the brain has neurons, this circuit would just about fill the Empire State Building. If it were built with conventional transistor circuitry closely packed, it would still fill an ordinary dwelling. With microminiaturization techniques, it might be reduced to the size of a room. We have at least one linear order of magnitude to go in order to equal nature's amazing circuit. I hasten to add that even if we had these ten billion circuit elements available, we would, by no means, know how to connect them up to simulate a brain. The problem of how the brain operates is still largely unknown.

Perhaps the most exciting developments in the information area relate to the large-scale digital computing machines. While the history of computers can be traced back many centuries, the most important ideas of modern computers were first discovered by the Anglo-Irish mathematician, Charles Babbage, about a century ago. With a remarkable prescience, he discovered the basic principles of a program-controlled computer and spent his life attempting to build one. Unfortunately, like many geniuses ahead of their time, his attempts failed, mainly because of lack of money and because he was attempting to do mechanically something that really required electronics.

Babbage's work was forgotten for some eighty years until about 1940. Then in at least three independent projects the principles of digital computers were rediscovered; at Harvard under Howard H. Aiken, at Bell Telephone Laboratories under George R. Stibitz, and at the University of Pennsylvania under John P. Eckert, Jr., and John W. Mauchly, with a strong assist from John von Neumann. Three programed computers were constructed, soon to be followed by many others at numerous laboratories, each generation of computers producing improvements over the last. The improvements took the form of increased speed, increased capacity, greater flexibility, and greater ease of programing, together with more compact designs and greater reliability. Since that time the dollars involved in computation have just about doubled every two years, and there appears as yet to be no

slackening of this exponential increase. In addition to the large-scale computers, there is a vast family of smaller or more specialized devices, and my own feeling is that the surface of this great mother lode has only been scratched.

What are the important features of a large-scale computer? First, it can carry out arithmetical and logical operations at incredibly high speeds. Current models operate in the microsecond range, and in the near future we expect to push toward millimicroseconds. Second, these computers can store and recover large amounts of information, including results of intermediate calculations. Finally, they can carry out a sequence of orders without outside help, this sequence or program representing a very complex calculation. The program can contain decision points, where the further operation depends on the results of previous calculations. Thus, the machine can make a proper choice when the time comes, even though the person who writes the program does not know which choice it will be. Perhaps more than anything else, these decision orders give computers a possibility of simulating in many ways complex logical decisions that we associate with the human mind.

We have had, then, just two decades of development of the computer in the modern era. The first of these, the decade of the forties, witnessed the construction of a large number of computers, each different from all the others, and going by such names as Eniac, Edvac, Univac, Illiac, and even Maniac. Most of these were built at universities and explored the possibilities of various types of logical organization, as well as new types of components such as different kinds of memory. Further, much work was done in learning how to use computers efficiently.

The uses of computers at this time were almost entirely straightforward computation, the solution of complex numerical problems arising in science and commerce.

During the decade of the fifties the development of computers largely passed from the university laboratory to the industrial research laboratory. Large companies began to manufacture computers and sell or rent them as a commercial product. There was still a good deal of research and development of new components, but it was more a matter of perfecting and improving than of innovating.

An important area of research during this period was that of improving communication between man and machine. The very difficult problem of programing was gradually reduced to manageable size. Whereas earlier it was necessary for man to talk in the machines' language, communication is now carried out in a language about halfway between that of the computer and that of man. It is now possible

for the average scientist to program his own problem after only a few days of study.

Another trend of growing importance became evident during the decade of the fifties. This was the growing realization that the potential applications of computers were by no means limited to ordinary numerical work—the solution of differential equations, or keeping bank accounts straight. Indeed, computers could be used for all manner of symbolic manipulation, involving abstract entities of almost any sort. Words, musical notes, mathematical expressions, wiring diagrams, or even pictures could be encoded into numbers and stored in a computer. Furthermore, almost any rules of operation or manipulation could be translated into a form understood by a general-purpose computer. Thus the doors were opened for a wild orgy of experimental programing, ranging from such things as playing chess to composing music, from translating languages to medical diagnosis.

So far most of this work must be described as experimental with little practical application. Much of it, in fact, is not intended for application, but rather to gain experience and knowledge relating to the possibilities in this general area. I feel, however, that this line of research is one of the greatest promise—a real indicator of the shape of things to come. It is interesting to take a quick look at some of the experimental programing that has been, or is being, carried out. This is an area in which there is a good deal of scientific wildcatting with many dry holes, a few gushers, but mostly unfinished drilling.

Language translation has attracted much attention, and many research groups are devoted to its study. As yet results are only mediocre. It is possible to translate rather poorly and with frequent errors but, perhaps, sufficiently well for a reader to get the general ideas intended. It appears that for really first-rate machine translation the computers will have to work at a somewhat deeper level than that of straight syntax and grammar. In other words, they must have some primitive notion, at least, of the meaning of what they are translating. If this is correct, the next step forward is a rather formidable one and may take some time and significant innovation.

Many computers have been programed to play various games, such as chess, checkers, bridge, or blackjack. By and large, the machines are now in the middle range of human ability, although in certain games particularly suited to their talents they will outplay any human.

To give just one example, A. L. Samuel has developed a program for playing checkers which plays a first-rate game. While a world champion can beat it, I would certainly bet on the 704 in a strong local tournament such as, say, the Houston Finals. Samuel's program is interesting in several respects. The machine is improving its play by a

learning procedure as it plays more games. It remembers parts of previous analyses and uses these later. Thus at times it may be seeing the game twenty or more moves in depth. It also may change its strategy in general form as time goes on.

It is also interesting that Samuel himself was only a beginner at checkers when he designed the program, and the machine beats him soundly. This shows that one can design a machine which does an intellectual task better than one's self, just as we can design steam shovels that lift more or automobiles that go faster than we can.

Another area of programing exploration is that of symbolic mathematics in contrast with solution of numerical problems. One aspect of this relates to the manipulation of expressions that occur in algebra and calculus—problems of factoring expressions, differentiation, and integration. These problems have all been tackled with excellent results. Differentiation is essentially a rote process and mainly, therefore, a matter of translating the rules into a program. Integration and algebraic manipulation often involve trial-and-error procedures and, for the mathematician, experience and insight. Nevertheless, it is possible to set up programs which will carry out these operations with a considerable degree of success. For example, an integration routine developed by Dr. James R. Slagle was sufficiently competent to pass an M.I.T. calculus test on formal integration.

Another aspect of symbolic mathematics is that of discovering and proving theorems, the work of the pure mathematician. It is possible to program a set of axioms and rules of inference into a computer, together with methods of looking for proof, and have it deliver proofs of various theorems. Thus, Hao Wang has programed a part of propositional calculus into a computer in such a way that it can prove many of the theorems in this area.

In particular, it was able to prove all the theorems in a large section of the famous Whitehead and Russell tract, *Principia Mathematica*, and it did this in less than five minutes. The authors of this work must surely have required many months to do the same job.

While on the subject of these rather exotic researches, I would like to mention a number of theoretical studies with biological repercussions. Lead by von Neumann, a number of investigators have studied mathematically and theoretically the matter of self-reproduction in a machine. Without going into details, one might summarize the results by saying that there is no theoretical reason why this should not be possible, although from a practical viewpoint complete self-reproduction by machine is at best a gleam in some mathematician's eye.

Another related question is that of self-repair and self-maintenance together with self-checking of errors in machines. Many computers

today have error-checking systems built in, so this is a realized goal. Self-repair is considerably more difficult, but some investigation has been made of this possibility.

Work has also been carried out in the direction of using computers to design various types of electrical circuits. These include such things as relay-switching circuits, diode-logic circuits, linear-filter circuits, and the like. In some cases the circuits designed were actually used in the next generation of computers. Thus we have perhaps the beginnings of self-reproduction in machines.

I should like to mention briefly also a creeping invasion of the arts and professions by the ubiquitous computer. In the arts, some of you may have heard the record *Suite for the Illiac*—music composed by the Illiac computer. While certainly not great music, its very existence brings to mind thoughts of a brave new world.

In the professions, lawyers have been working with the possibility of using computers for the study of legal precedents and other information-retrieval problems. Doctors are studying the possibilities of computers as a diagnostic aid. Teachers are investigating the possibility of teaching machines which may range from a simple question-and-answer device to a full-scale computer acting very much like a private tutor. The second industrial revolution may displace us at all levels, from the factory hand to the skilled professional.

For the most part, computers so far have been used as straight information-processing devices. Instructions are fed in by a human operator and answers typed out for a human operator. The only connection of the computer to the real world is through the operator. A most interesting area of study is that of giving a computer its own sense organs so it has direct knowledge of the outside world, and manipulative means, the equivalent of hands, so that it can act directly on the outside world. Of course, this is done in the automation of factory equipment, but here the outside world is so limited that the machine has very little in the way of freedom of action or of unexpected surroundings. Is it possible to add sense organs and motor organs to a computer so that it is something like the robot of science fiction? One study along this line was carried out by Dr. Heinrich A. Ernst at M.I.T., in which he coupled a mechanical arm of the type used in nuclear research to a computer. The arm was supplied with primitive sense organs of touch and given a program allowing the computer to maneuver the hand with seven degrees of freedom. The hand was able, for example, to feel around on the floor and pick up blocks and then stack them in a tower or to deposit them in a wastebasket. This is only a beginning, and many difficulties are encountered in this line of research. Perhaps the most challenging is that of developing a sense

organ comparable to the human eye which can be coupled directly to a computer. Recent studies of the operation of the frog's eye and also work in progress on the abstraction of object content from a picture may eventually alleviate this problem.

The various research projects I have been discussing and many others of similar nature are all aimed at the general problem of simulating the human or animal brain, at least from the behavioristic point of view, in a computing machine. One may divide the approaches to this problem into three main categories, which might be termed the logical approach, the psychological approach, and the neurological approach. The logical approach aims at finding a straightforward method, in logical terms a decision procedure, which will solve all of the problems of a given class. This is typified by Wang's program for theorem-proving in symbolic logic. It is most effective and efficient when it can be done, but not all problems have available a suitable decision procedure. Furthermore, a decision procedure requires a deep and sophisticated understanding of the problem by the programer in all its detail.

The second method, the psychological approach, is often referred to as heuristic programing. It involves a study of how we solve problems, perhaps by subjective or introspective analysis of our own thought processes. We then attempt to translate these heuristic methods of trial and error and the like into a program for a computer. The integrating program of Slagle is an example of this method. I believe that heuristic programing is only in its infancy and that the next ten or twenty years will see remarkable advances in this area. This may also have important fringe benefits in that we may understand far better the processes of creative thinking and perhaps be able to teach them to some extent to others.

The third or neurological approach aims at simulating the operation of the brain at the neural level rather than at the psychological or functional level. Although several interesting research studies have been carried out, the results are still open to much question as to interpretation. While neurophysiologists have uncovered much information regarding the operation of individual neurons and their general patterns of interconnection, the mode of operation of the brain is still a wide-open scientific question. It is not, for example, as yet known where memory takes place or by what means. Thus anyone attempting to construct a neural-net model of the brain must make many hypotheses concerning the exact operation of nerve cells and with regard to their cross-connections. Furthermore, the human brain contains some ten billion neurons, and the simulated nerve nets of computers at best contain a few thousand. Under these conditions one

could only hope for the most primitive type of brain activity in the model, and consequently the experimental results are difficult to understand. This line of research is an important one with a long-range future, but I do not expect too much in the way of spectacular results within the next decade or two unless, of course, there is a genuine break-through in our knowledge of neurophysiology.

With the explosive growth of the last two decades in computer technology, one may well ask what lies ahead. The role of the prophet is not an easy one. In the first place, we are inclined to extrapolate into the future along a straight line, whereas science and technology tend to grow at an exponential rate. Thus our prophecies, more often than not, are far too conservative. In the second place, we prophesy from past trends. We cannot foresee the great and sudden mutations in scientific evolution. Thus we find ourselves predicting faster railroad trains and overlooking the possibility of airplanes as being too fanciful.

However, we may certainly expect in the near future to see continued improvements in types of components and surely the development of many new computer components. The next generations of computers will be faster, smaller, with greater flexibility and memory capacity, and more reliable. We may expect the programing to progress so that it becomes easier to communicate with computers using our own language or something close to it. We may expect computers to be applied in many new areas; thus the stock market is planning computer innovations. Many commercial enterprises will find computers efficient and economical.

At the intellectual level and taking a longer-range view, I expect computers eventually to handle a large fraction of low-level decisions, even as now they take care of their own internal bookeeping. We may expect them to be programed for a wide variety of types of symbolic information-processing and general problem-solving, replacing man in many of his semirote activities.

I further expect the development of high-grade sensory and motor organs, the equivalent of the eye and the hand, for computers, leading perhaps eventually to autonomous robotlike devices which might be smart enough to do housekeeping.

Many people are concerned with regard to the impact of automation and computers on our economic and social life. It is clear in the first place that there is no way to stop or slow down this type of scientific research any more than work in any other field of science. Good or bad, these trends will continue. Our computers will become more sophisticated, and our automation will invade more and more areas. As in the first industrial revolution, there will necessarily be

technological unemployment, economic hardship during relocation, and the like. But again, as in the first industrial revolution, automation makes possible a larger gross national product for the same total man-hours of work. Thus if we desire a higher average standard of living or more leisure, automation leads in this direction, provided only that we can solve the problem of equitable distribution of this larger work product. This last problem is, of course, most difficult, but, nevertheless, one feels that an intelligent scientific attack on it should lead to a solution.

Another problem often discussed is: What will we do if the machines get smarter than we are and start to take over? I would say in the first place, judging from the I.Q. level of machines now in existence and the difficulty in programing problems of any generality, that this bridge is a long way in the future, if we ever have to cross it at all. I would also suggest that if we can ever make machines much smarter than we are we can also perhaps make them much wiser, and possibly *they* will help *us* find a peaceful coexistence!

JACOB VINER

The United States as a "Welfare State"

I PLAN in my lecture to compare the pattern or "style" of the present-day American economy with earlier patterns here and elsewhere and with currently prevailing patterns elsewhere. To do so I must make use of abstract and ambiguous labels for different kinds of economic systems, much as I would prefer to be able to dispense with them. There are only three other alternatives that I can conceive of, and none of these is a practicable one. I could make use of a set of labels which are not abstract, which have precise and uniform meaning regardless of time or country, and which have the quality of automatically and accurately communicating that meaning to any audience, whether a sophisticated one like the one that is honoring me at this moment by permitting me to address it or a naïve and simple-minded one. But such a set of labels does not exist in the field of economics or of any of the social science disciplines. Or I could dispense with labels and each time that I refer to a particular economic system or pattern repeat the full inventory of its fundamental characteristics. Or I could do so only upon first reference to a particular system, thereafter using such colorless and un-mnemonic symbols as System A, System B, and so forth. Either of these latter procedures would lead to intolerable boredom for you, and perhaps also for myself. There is therefore no escape from the use of labels too simple and uninformative for the ideas they are intended to communicate.

In controversial fields, however, labels in the course of the history of their use inevitably lose some of the objectivity they may have had when originally invented and become carriers of undertones of praise or blame, thus becoming substitutes for rational thought instead of its tools. These undertones, moreover, are liable to be random and undisciplined and to vary with the period, the region, and

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the persons using them or hearing them used. The greatest of the risks connected with the use of labels is that when a speaker intends one undertone to be caught by his audience, the audience will catch a different one. I know no way whereby these risks and uncertainties can be completely overcome, and no way but continued and disciplined exchange of views conducted in a spirit of cool and mutually tolerant discourse by which they can be reduced to moderate dimensions. I can only affirm that it is not my purpose on this occasion to persuade or to convert anyone to anything, to comfort anyone, or to antagonize anyone, and that even if such were my purpose I would do my best to confine myself to logical discourse rather than semantic tricks. But words are treacherous tools, and no matter who is pouring them out on you, eternal vigilance is in the last analysis your only effective defense against being betrayed by them. I have at least put you on your guard.

I choose as a convenient label for the present-day pattern or style of organization of the American economy "the welfare state." The term is of German origin and seems first to have been used in the 1870's by German economists as a term of praise for the social goals of Bismarck and the legislation he was initiating to promote them. With substantial similarity in meaning it is being widely used today to describe the existing or the desired pattern of economic organization in the industrialized countries this side of the Iron Curtain. It is fairly frequently used as a label for the American economic pattern as it has evolved especially since the initiation of the New Deal, although in the United States other labels are sometimes preferred: for example, "people's capitalism," "welfare capitalism," "the mixed economy," and, by critics on the right, the "mixed-up economy" and "cryptosocialism"; by critics on the left, "monopoly capitalism," "decadent capitalism," "Madison Avenue capitalism," and, as the most recent derogatory term to obtain wide currency, the "affluent society." The purport of this last term seems to be to associate with our notions of the quality of our existing system the depressing idea that under it all classes have more income even after taxes than they know how to spend wisely and yet refuse to let the government decide for them the choice between the available range of commodities and services which their incomes shall be used to procure.

It is easier to be precise on what the welfare state is not than on what it is. Like the aristocratic or theocratic societies prior to the Industrial Revolution, and like socialism, communism, fascism, nazism, but in lesser degree than all of these, the welfare state is a rejection of the laissez faire or "liberal" system which substantially prevailed in the Western world in the nineteenth century, and this

halfway or partial rejection of laissez faire is, I think, the most uniform and the most important distinguishing mark of the welfare state. By laissez faire is meant, of course, a system under which the intervention of government in economic matters, whether as regulator or operator, is confined to the barest practical minimum consistent with the maintenance of order, the enforcement of contracts, the protection of individuals against direct and overt coercion by other individuals, and the maintenance of the military personnel and facilities necessary for defense against external aggression. In the nineteenth-century liberal society the emphasis was on freedom for the individual from government, not on service to him by government. In the modern forms of authoritarian state the emphasis is on service to the individual, with the character of the service determined from above and with statist coercion substituted for the political and civil freedoms of the liberal society. The welfare state tries to find a middle path between service without freedom and freedom without service.

In the liberal nineteenth-century state rich and poor were in principle equally protected from encroachment on their property rights, their rights to follow the occupation of their choice, to live where they pleased, think and say what they pleased, and spend what they had the means to spend on things of their own untrammeled choice. For the organization of the productive process, for the attainment of equilibrium as between what producers chose to produce and what consumers chose to consume, for the determination of the ratio in which income currently produced should be allocated to current consumption or be saved and invested, reliance was on competitive market forces. That competition left to its own devices might lead to private monopoly was either overlooked or denied or believed to be adequately guarded against if government itself refrained from establishing or promoting private monopoly power and enforced the common-law prohibitions of overt conspiracy in restraint of trade.

Wealth always brings to its possessors power and privilege. The privileges which the rich specially enjoyed under laissez faire, however, were for the most part not privileges conferred upon them by government but arose directly or indirectly out of their possession of sufficient wealth to buy such things as education, medical services, gracious mansions, leisure, art, and mistresses. The most ambitious, the most intelligent and gifted, the most lucky of the working classes succeeded in increasing numbers, but for the most part without substantial assistance from government, in acquiring moderate shares in these material means to the good life, and many of these rose into the ranks of a rapidly growing middle class, which was eventu-

ally to impose on most of the Western countries the substitution of democratic political institutions for the absolutist or the aristocratic regimes of the past.

In the nineteenth century average incomes appear to have risen impressively in all of the Western countries, although there is a great scarcity of reliable statistical information. But this increase in average income was in Europe at least in large part and perhaps wholly the result of the relative rise in the size of the middle classes as compared with the working classes. The lower classes gained from the progress of technology some improvement in health and in mortality and some improvement in the lighting and heating of their homes. On the other side of the ledger for them, however, was the increasing congestion and the decreasing access to sun and air and light in their homes, and apparently also deterioration in the quality of the food they ate and the clothes they wore. As best I can determine, it was not until about the 1870's that it can be said with assurance that the standard of living of the bottom 50 per cent of the population of any western or northern European country was clearly and substantially higher than it had been in, say, 1820 or 1750 or 1650 or perhaps even 1550. It was not, I think, chiefly political democracy that brought the genuine improvement which did occur from the 1870's on, but largely the cheaper and better food from North America, the Argentine, Australia, and New Zealand which the application of steam to ocean and land transport made available to western Europe, and the decline in the working-class birthrate which resulted from the widespread resort to birth-control practices beginning in the 1870's.

Political democracy, laissez faire, and the persistence of mass poverty for the working classes while above them were conspicuous expenditure and growing accumulated wealth—these together constituted an unstable mixture which could not last. It gave rise to socialist movements of several species, and it may be that the fact that the latter failed everywhere before the First World War to bring about an explosion of the mixture was largely due to the circumstance that the governments of the time were prudent enough to grant the newly enfranchised masses political platforms from which to voice their complaints and that a foretaste of the welfare state, such as the Bismarckian social legislation in Germany and the Lloyd George death duties in England, as well as the growth in strength of the trade unions, opened up vistas of the possibility of reaching the Promised Land by milder means than revolutionary socialism. In any case, the welfare state of today has its roots in the nineteenth-century dissatisfaction of the working classes with the

workings of laissez faire capitalism. The welfare state also constitutes a partial rejection of the alternatives to laissez faire which nineteenth-century socialist movements proposed. Let me now turn to a more positive description of the characteristics of the welfare state.

In the welfare state the central and subsidiary governments engage in a wide range of economic activities. They accept responsibility for ironing out the business cycle, for relief of the unemployed, and for an extensive program of cradle-to-grave insurance against the normal hazards of life. They encourage and regulate collective bargaining between employer and employee with respect to wages, hours of labor, and working conditions, usually with what on nineteenth-century criteria is an open and systematic bias in favor of labor. Through progressive tax systems and expenditures directed largely to the subsidization of the low-income sections of the country and sectors of the population, they claim to exercise a strong equalizing influence on the distribution of wealth and income.

With respect to free competition in the market, they are torn between two opposite doctrines: on the one hand, the doctrine that free competition is the most effective stimulus to improvement, leads to the closest approximation of material rewards to social contribution, and maximizes flexibility and adaptability to changes in tastes, processes, and relative abundance of productive factors, the fundamental proposition of nineteenth-century laissez faire liberalism; on the other hand, the doctrine that free competition leads to duplication of facilities and services, to booms and busts, to the crushing of the weak by the strong, and eventually to private monopoly. They thus embark on extensive and improvised rather than precisely designed programs of governmental intervention. These programs leave a large measure of freedom to market forces and to individual initiative—or lack of it—but they involve a wide range of activities of a regulatory or supervisory character. These programs include also many types of more direct participation by government in economic activity, including even some measure of substitution of government for private operation of industry. Selected industries, especially agriculture, are shielded from the full rigors of competitive forces by subsidization, price supports, preferential tax treatment, and government stock-piling.

The volume and allocation of capital formation are deliberately influenced by subjection of capital issues on the market to licensing, by setting up governmental credit agencies which increase the availability of capital at low rates for selected industries by direct lending of government funds, and by guarantees of repayment to private lenders, the industries so favored being selected on the basis of a

variety of social policies and political grounds, but always in response to special concern for the prosperity of particular sectors of the population. In the United States, for example, agriculture, the housing needs of the low-income classes, small business, and ocean shipping are given special favors, and here, as in other welfare-state countries, decaying industries and new pioneer industries are given aid to the recovery of strength or to its new acquisition.

In response to special needs or to political strength, the welfare state typically deals ambivalently with monopolistic practices; in some sectors it combats them by antitrust and anticartel legislation; in other sectors it sanctions and even enforces them, as (to take the United States as an example) in the case of agriculture, in the sanction of price maintenance in the field of retail distribution, and, above all, with respect to labor-union practices. "Natural monopolies" such as railroads, urban mass-transportation facilities, electricity and gas generation and distribution, dock facilities, bridges, and roads are either owned and operated by governmental agencies or are closely controlled as to rates and quality of service by government. But this feature of the welfare state is in the main but a moderate extension of the "municipal socialism" which became common from the 1870's on as the working classes won a greater measure of political power. "Nationalization" of industry outside the area of public utilities is not a prominent feature of the welfare state, and its substantial absence from program and practice today is perhaps the most important fact justifying the drawing of a sharp distinction between even the democratic socialism of the nineteenth century and the present-day welfare state. In the welfare state education is made widely available, is overwhelmingly conducted in governmental institutions, and when left in private hands is usually both substantially financed and closely regulated by government.

To finance their activities and also to make taxation serve as an instrument for redistribution of the national income, welfare states collect in taxes up to 30 per cent or more of the national income. Income taxes are invariably steeply progressive and taxes on business are heavy, and in general the total effect of the tax and expenditure activities of the welfare state is probably in a significant degree such as to make the national pattern of income distribution a less unequal one than it would be if all tax revenues were derived from a proportional tax on income and if all governmental expenditures in their immediate impact bestowed benefits on individuals in conformity with the over-all pattern of national distribution of income. But all the welfare states have democratic processes of government including universal suffrage; in all of them the middle classes and those of the

lower-income groups who have absorbed "bourgeois" attitudes are a great and often preponderant portion of the total population, and welfare-state politicians, like all politicians, are highly sensitive to strategically located and well-organized aggregates of voting power. The welfare state is consequently nowhere exclusively and rarely predominantly a "proletarian" state. It is often, at least intermittently, a "bourgeois" or middle-class-dominated state. In consequence, whatever its proclaimed program of income equalization may be, its tax bite is rarely as strong as its tax bark. Even when income- and inheritance-tax rate schedules are in appearance progressive to the point of near expropriation of the high-bracket incomes or estates, they are invariably accompanied by an elaborate set of loopholes which temper the tax winds for the partially shorn sheep.

Government subsidies, moreover, do not flow exclusively to the very poor, and even though predominantly it is rich Peters who are taxed to pay poor Pauls, to a substantial extent the net outcome of the complex tax-and-subsidy system is that Peter is taxed to pay Peter, after deduction of an appropriate charge to reimburse the government for its services in keeping the taxpayers' money in circulation. In the welfare state instances are even to be found where the very comfortably well-off succeed in one way or another in getting on the dole in forms and dimensions which add to the social status of the recipient instead of, as in the case of poor relief, detracting from it. To a liberal or to an old-fashioned socialist, this may seem a funny way to run a country, but it is a significant characteristic of the welfare state that it is essentially a democratic response to the whole range of popular interests, values, and aspirations, and that in consequence its general pattern is bound to lack complete internal coherence and to display to the scrutinizing eye instances of gross inconsistency.

To conservatives of the American type, this concern of mine with the selection of an appropriate label for our present-day economic system would probably seem superfluous trifling with the obvious, since the century-old term "socialism" would adequately serve all purposes, or at least all *their* purposes, and a fresh label would not lessen the menace of the poison. I would not only concede but would emphasize that the modern welfare state embodies substantial elements of nineteenth-century democratic socialism. I would even concede the reasonableness of applying to it some such label as "new socialism" or "neosocialism," or even "twentieth-century democratic socialism," provided it were conceded that "new capitalism" or "neocapitalism" would not be an appreciably more misleading term for it and provided it is not claimed that there are no important differ-

ences between the programs of nineteenth-century socialist movements and the practices of present-day welfare states.

Nineteenth-century socialism in all of its variants was the doctrine of groups out of power and with no early prospects of power. The orthodox Marxian socialists had a doctrine of criticism of the capitalism of their time and a program of revolutionary overturn of it by an elite acting on behalf of, though not itself members of, the proletariat. Marx and his most loyal disciples carefully refrained from spelling out any of the details of social organization that would be introduced "come the Revolution." To what extent this was the result of utopian dreaming, as the proposition that under socialism "the state would wither away" suggests, or was strategic concealment of firm intentions, is still a matter of debate among both friendly and hostile students of the sacred Marxian texts. But from the Marxian critique of nineteenth-century liberal capitalism we have every right to infer that the Marxian aspirations included the complete abolition of private property in the tools of production, a regime under which all able-bodied adults would have to work if they wanted to eat, and suppression of the allegedly sham freedom of political democracy.

The present-day practices of the welfare state do not conform to any of these three goals, and with a minor qualification with respect to nationalization with which I will deal later, none of these is given a place in any welfare-state program I know anything about. Marxian socialism also had a decided equalitarian bias, and "from each according to his capacity and to each according to his needs" sounds clearly to my ears like an equalitarian slogan even if I don't claim to know what it means or for that matter what "equality" as a rule for distribution of income would mean in precise terms. I am sure of one thing, that in the heaven of original Marxianism or in the present-day Communist version of it as it operates in Russia and elsewhere, the rule of equality closely resembles the leaden Lesbian architectural rule which Aristotle speaks of which adapted itself to every bend or curvature of a wall that appealed to the designing architect's fancy or judgment. In the present-day welfare state there is no doubt a widespread belief in the virtue of "equalization" of income if that is interpreted to mean the gradual elimination of extremes both of wealth and of poverty. Beyond this, I see no clear signs of more ambitious plans or of more radical practice. The welfare state is a threat to the top 10 (or perhaps 5) per cent of its population in terms of the amounts of wealth or disposable income after taxation they will be allowed to retain, and a promise, a realized one in a number of countries, for the lowest 10 or perhaps 20 per cent of the population, in terms of the minimum standard of living that will be guar-

anteed to them. This may be good or it may be bad, but it is a far cry from Marxian socialism.

Let me now compare the present-day welfare state with non-Marxian nineteenth-century socialist philosophy, although this is to compare a working system without a philosophy with a philosophy which never had the responsibility of application, and whose many and highly changeable programs were therefore more directed toward harvesting votes than drawing up blueprints for whose practicality they had need to worry about. All the nineteenth-century democratic-socialist movements, however, did emphasize "nationalization" of the facilities and instruments of production and a large measure of equalization of income. Such proposals retain a place in the formal programs of some important socialist parties which today operate in welfare states and which are or have been in power. But there is no evidence that outside their minority left wings there is any serious intent on the part of these "socialist" parties actively to pursue these goals, and there is abundant and growing evidence that the present trend of democratic-socialist thought is to abandon these goals as obsolete, as unnecessarily extreme, and as a menace to the political success of the socialist parties in election campaigns.

What seems to have happened is that the socialist party leaders have realized that the middle classes who are terrified by the preaching of such goals are steadily growing in numbers, that political power cannot be maintained or attained unless large numbers can be won over from among the middle classes to their ranks, and that the wage earners themselves are reasonably content with the progress they have made despite the absence of nationalization and of radical equalization; that these latter have not found their status or income or incentives or working conditions appreciably improved when the government has substituted itself for the capitalist as their employer, and indeed that they have in large part absorbed the values and the attitudes of the middle classes and cannot be depended on to continue to give loyal support to parties calling themselves "socialist" or "labor" if these actually and vigorously pursue extreme policies.

Part of the loss of zeal within the socialist parties for fargoing equalization of incomes as a major goal stems from a newly acquired disposition to recognize that in any social system income differentials are essential elements of an adequate set of incentives to effort, to acquisition and exercise of skill, and to assumption of managerial responsibilities. Increasingly also there is belief even among socialists for whom the idea of "equality" has great moral appeal that as a fact of life the maintenance and expansion of a cultural elite, the promotion of creative art and the skilled and dedicated diffusion of

its fruits do or may require that special material incentives be provided for gifted persons to develop their capacities, and that the conditions of their working life must for such persons be made easier and more removed from discomfort, enforced toil, and responsibilities for family support, than for the ordinary run of worker. Important also has been the realization, with the growth and improvement in quality of statistics of income, of how modest would be in most countries the improvement in economic status of the poorer 50 per cent of the population if there were divided equally among it the wealth, or the wealth and income, in excess of the national average of, say, the richer 50 per cent of the population.

While these socialist or labor parties have consequently been moving visibly toward the right in philosophy and in action, all but extreme wings of the parties right of center have been moving toward the center or perhaps even beyond it. Party affiliations are, of course, more closely tied up with class structure in the European welfare states than in the United States or Canada and are emotionally bound to historical traditions of passionate participation in major struggles for principle and for power; interclass mobility is much less free in Europe than in this country, except that in this country racial and religious barriers are important. Party distinctions, therefore, mean more and are more stable in Europe than here, and I am not claiming that because the parties there are moving closer to each other there is real prospect that the distinctions between them in goals and attitudes will cease to be important. All that I claim is that except for extreme wings of small size and limited range, all the major democratic political parties in Europe operate well within the limits of tolerance of the welfare state and that no threat exists (France perhaps excepted and for other reasons than purely economic issues) of violent social strife in these countries in the absence of subversion by agents of external forces.

The parties of the left which continue to call themselves socialist may or may not be justified in doing so. In most European countries, as in almost all underdeveloped countries, it seems to be good strategy for a political party to carry a "socialist" or "social" label. In the United States and in Canada, on the other hand, it seems clear that it would be political suicide. But whatever labels modern political parties of the left adopt for themselves, all the major parties of the left in the welfare states differ in important respects in programs, in attitudes, in convictions, and in their practice when they gain power from the socialist parties of pre–World War I of which they are the historical heirs. They are not revolutionaries even when political victory by democratic process seems to be beyond their reach,

and they are not authoritarians, or prone to engage in large-scale nationalization, or radical equalizers of income, even when they do gain power. They are constitutional parties, and they know, or believe, that their strength would evaporate if they showed signs of losing faith in democratic process and in the adequacy of persuasion by argument and exhortation as the means whereby to retain and to augment their strength.

In the underdeveloped countries many socialist parties are, however, quite close in their programs and doctrines to the European socialist philosophy of the nineteenth century. They lack democratic traditions, and the economic and social problems they face seem more serious and less susceptible of solution or even of palliation than the corresponding problems of western Europe today, or even fifty or a hundred years ago. The population problem is for them a major and perhaps incurable problem within a space of time short enough to be tolerated. The mild remedies by which the advanced countries succeeded in eliminating all but minor residues of the plague of desperate mass poverty (which a hundred years ago prevailed in most of Europe nearly as virulently as it does today in much of Asia, Africa, and Latin America) to many observers do not seem to be effective or appropriate in the setting of the underdeveloped countries. Middle classes are small and relatively unimportant in a majority of the underdeveloped countries, and the gulf between the very rich and the very poor is emptier and wider than it ever was in western Europe, to say nothing of the United States and the European-colonized members of the British Commonwealth.

In much of the underdeveloped world violence as an instrument of social change is not held in abhorrence, and democratic processes of making social decisions are either weak and without the backing of long-established traditions and values or are nonexistent. Social change by means of violent revolution, of expropriation and confiscation of the property of the rich, of nationalization of existing industry and establishment under government ownership and management of new industry seem to many in these countries and to some of their friends in welfare-state countries to be their only means of escape from deepening misery and total despair.

For this and other reasons the United States has for about a decade been attempting to nudge them, with the assistance of American financial aid and technical guidance, to adopt welfare-state or "moderate" programs as the remedy for their ills. Their problems, however, may be too deep-rooted and the material and human resources available to them too scanty to make moderate reform either in fact or in appearance sufficient to meet in time and degree the minimum de-

mands which the aroused expectations of their masses lead them to press on their governments. The suppression of human rights, the cruelty, the totalitarianism of the Iron Curtain countries do not deeply shock them, for these are evils which for centuries they have learned to live with. Many in these countries are convinced that some of the Communist programs of social change have been effective for the Communist countries and would be effective for them in providing food, health, education, and status for the masses, in reducing to tolerable proportions the gap between rich and poor, and in endowing them with the mass-production factories which have become for them the outstanding marks of successful economic development.

In guarded fashion high officials and distinguished experts in this and other welfare-state countries are of late revealing in what seems to be a growing tide of opinion that they also are becoming convinced that the methods by which prosperity has been attained in Europe and North America are too mild, too slow, too dependent on a rich foundation of accumulated wealth, of natural resources, and of trained personnel to be adequate to cope with the problems facing the underdeveloped countries. It seems clear that to some extent the American government itself is today trying to convert the better-off classes in some of the underdeveloped countries to acceptance of measures encroaching so drastically on traditional property rights that they would be regarded with horror and apprehension if proposed in this country by any responsible person. If newspaper accounts are to be trusted, the adoption of methods of social change which in their radical character go "beyond the welfare state" with respect to permissible procedures is to some extent being made a condition of continued eligibility for American foreign aid. It may be that this is a sign on our part of maturity and of freedom from excessive doctrinairism and of a willingness to perceive and to face uncomfortable facts. As a believer in the great long-run virtues of patterns of due process and of respect for long-established human rights, including property rights, I am, however, very deeply concerned about this, and I feel that there is urgent need for sober and balanced public discussion of the issue, lest we find ourselves committed, when it is too late to retreat, to pushing the underdeveloped countries more rapidly than is safe for us or for their peoples down a slippery and perilous slope.

This may be too pessimistic a view of the prospects that the undeveloped countries will seek and find cures for their economic and social ills in programs which can be reconciled with democratic processes, and with the preservation of some degree of respect for the long-established rights and the willingness and capacity to render valuable services to the common good of a reformed, enlightened, and

self-disciplined, propertied middle class. Financial and technical aid from the richer countries, more generous tariff treatment by these countries of the commodities which are and will long continue to be the staple exports of the underdeveloped countries, break-throughs through research and experiment to the discovery of successful means of adapting to tropical soils, tropical climates, and tropical and semi-tropical cultural patterns of the great stock of scientific and technological knowledge which is at their disposal in the advanced countries or can be made available to them—these may yet serve to make the underdeveloped countries safe for democracy and to make democracy seem to them unqualifiedly safe for themselves. Even more important in my perhaps biased opinion would be the discovery of cheap, simple, and effective methods of birth control whose widespread use would not be prevented by ignorance, by cultural prejudices, and by religious dogmas kept in a frozen state of rigidity and immunized from the processes of "progressive revelation" and of "development" of dogma which for both Protestantism and Catholicism have at critical periods in the social history of mankind been invoked to permit religious faith to serve as a powerful aid to social reform rather than operating as a stubborn and irrational barrier to it.

If I may return to the domestic scene, the United States is about as fully a welfare state now as any other of the advanced and democratic countries, including those like the Scandinavian countries and New Zealand whose regimes, intermittently at least, are in the hands of political parties which bear with pride the socialist label. There are features of the American economic system which are somewhat special to it, but these for the most part do not derive their importance from their relationship to or independence of the philosophies of nineteenth-century non-Marxian socialist movements and their modern heirs. In its ideology the American public, and especially its more conservative sectors, clings more faithfully to the maxims and stereotypes of nineteenth-century laissez faire than do even the European prototypes—if such there be—of the National Association of Manufacturers, the United States Chamber of Commerce, or the American Medical Association. But these are in large part merely semantic loyalties on our part, rather than operative rules for actual behavior. Laissez faire in fact was notoriously not the ruling principle of our captains of industry when it was the tariff that was in issue. This ideological conservatism on our part probably renders us a useful service to some extent, perhaps in preserving for us old elements of policy which deserve to be preserved or to be resuscitated, but most obviously in fostering a scrutinizing and critical inspection by the American public of all proposals for change.

The welfare state is at best a hastily improvised system having characteristics stretching all the way through the range from near-statism to near-anarchy. It is an unplanned response to a host of historical forces and of political pressures which has not yet acquired, and may never acquire, an internally coherent and logically formulated philosophy. It is undergoing constant change, and its movements, forward, backward, and sideways, are not guided by any clear and widely accepted consensus as to where it is going or where it should go from here. It needs critics more than advocates or prophets, and there is applicable to it the saying "Woe unto Israel if the prophets should ever get the upper hand!" Theodore Roosevelt many years ago thought he perceived a lunatic fringe to every popular movement for reform, but was blind to the fact that there are lunatic fringes on the right as well as the left. But even these fringes, while scarcely ornamental, have some utilitarian services to perform. They press the advocate to seek for good reasons to support the causes he is preaching, and they stimulate the voter to ask the promoter of a new idea to stand up and defend it. Even blind resistance to change increases the probability that the over-all quality of the changes that will be made will be higher than in its absence.

It is not because of a unified and coherent social philosophy that it realizes in practice but rather because under it the working classes are reasonably satisfied with their present status and see substantial promise of improvement in it for their children even when not for themselves that the modern welfare state has strength and capacity for survival. In one of his poems, Robert Frost asks:

> . . . How are we to write
> The Russian novel in America
> As long as life goes on so unterribly?
>
> (*New Hampshire* [1923])

It is not only in America but throughout the free world where the welfare state prevails that there is no prospect and no wish that the "Russian novel" be written. But if in these countries life for the masses was not "unterrible" and if the more fortunate few in these countries showed no compassion for misery and used their power to resist all change, all that would be needed would be the appearance of a demagogic leader to make imminent the danger of a violent social revolution which would make no fine distinctions between the good and the evil in old traditions and institutions and would bring toppling down upon both the well-off and the poor the debris of a social system which through lack of understanding, of sympathy for dis-

tress, and of prudence had failed to take the steps necessary if it was to earn and assure its survival.

It is a special characteristic of the American form of welfare state that its political structure makes even more unlikely than for other welfare states close correspondence between a coherent social philosophy and the predominant pattern of social practice. The American system is marked by extreme diffusion of legislative, judicial, and administrative power, and even if consensus of doctrine were almost complete on the part of the public, the machinery for translating this into consistent and co-ordinated practice would be lacking in large degree. There is, first, the "federal" aspect of our constitution, which involves a sharing of ultimate sovereignty between the national government and state governments, with the line of demarcation of powers, though shifting in response to technological change and to the processes of change in the social philosophy of our supreme judiciary, persisting as a barrier to effectively centralized national social planning.

There is, second, the constitutional separation of powers between national executive and national legislature, with much less concentration of power except in major emergencies in the hands of the executive than prevails under the parliamentary forms of government which almost all other welfare states follow, and which brings it about that in the United States there is much greater scope than elsewhere for conflict and deadlock between executive and legislative, and need for much greater resort to *ad hoc* compromise in the processes of formulation and execution of the grand strategy and the day-to-day tactics of policy.

There is, third, the division of power between the Senate and the House of Representatives, which makes their relations a close analogue to the "duopoly" of economic theory where for over a century the best minds in the economic profession have utterly failed to discover a formula which describes realistically the mode whereby the inevitable conflicts of interest and of objectives between the two equal powers obtain resolution.

There is, fourth, the almost promiscuous and haphazard dispersal of power within each branch of the legislature, where the weakness of party discipline and the possession of nearly unlimited veto power and delaying power by the committee chairmen, who acquire their posts by seniority regardless of the degree and quality of their ability, of their loyalty to the President, or of their loyalty to their party, result in the processes of legislation being largely subject to the idiosyncrasies and the special interests of a small group of men whose qualifications for meeting the heavy responsibilities they bear, whether

it be qualities of ability or of character, are even more subject to the hazards of chance than the outcome of a horse race or a football match.

There is, fifth, the substantial power of the run-of-the-mill congressman or senator in initiating, delaying, or modifying specific legislative proposals, which results in making extremely difficult and even impossible the attainment of coherence, timeliness, and self-consistency in the legislative processes as a whole, and in making unduly important the role of the lobbyist for special interests, private or regional, who to attain his objectives, good or bad, often needs not the approval of the President or of the Administration or of the majority party as a whole or of national public opinion or of the press, but only the dedicated and not necessarily disinterested support of a small handful of free-wheeling legislators.

There is, finally, the power of the judiciary, subject to no formal limits except its own standards of judgment and discretion and its own interpretation of its constitutional function and authority, to find *ultra vires* the outcome of the legislative process and even to engage in the equivalent of legislation itself, through its execution of its duty to interpret the intent of Congress and its practice of "filling the gaps" in acts of Congress in the course of its adjudication of specific cases that come before it for decision.

For all these reasons and for additional reasons which limitations of time or of my knowledge and insight prevent me from bringing to your attention, there is in the abstract no reason for making an idol of the welfare state in its American form or for dedicating ourselves unreservedly to its continuance as it is today without qualification or amendment. Given the complex and puzzling problems it is continually facing, the imperfection of the procedures whereby it deals with problems which it cannot evade or defer or with problems which special interests may press upon it for premature resolution, it would be only by the dispensation of a benevolent Providence that it would ever make precisely the right decisions or always avoid major mistakes. It does not have theoretical superiority over all conceivable alternative systems nor ability to register faithfully and accurately the national consensus on every issue that comes before it, on many of which Congress and the President often show that even they had been unaware of just what is wanted and just what should be done until at the termination of the confused and muddled legislative process they examined what they had in fact done. If, therefore, I nevertheless conclude that I believe that the welfare state, like Old Siwash, is really worth fighting for and even dying for as compared to any rival system, it is because, despite its imperfections

in theory and in practice, in the aggregate it provides more promise of preserving and enlarging human freedoms, temporal prosperity, the extinction of mass misery, and the dignity of man and his moral improvement than any other social system which has previously prevailed, which prevails elsewhere today, or which, outside Utopia, the mind of man has been able to provide a blueprint for.

A traveler on a main but congested highway said to a local yokel that his map indicated that there were two side roads at that point which were shortcuts to his destination, and asked for advice as to which of the two to shift to. To which the yokel replied: "Whichever of the two you take, mister, you will wish to God that you had taken the other, or neither." That is how I feel about the availability of other paths to the good society than that which the welfare state provides, strewn as that path is with boulders, pitfalls, detours, and unpredictable as is its ultimate terminus.

JEAN LERAY

Cauchy's Problem

SINCE RICE UNIVERSITY was inaugurated fifty years ago, so many things have happened in mathematics that no one could describe them in fifty minutes; allow me to tell you the story of only one problem, but a characteristic one—Cauchy's problem.

It arises in mechanics: The motion of a mechanical system has to be calculated with respect to its laws of motion, which is a differential system, and to its initial position and velocity, which are data defining a special solution of that system. Cauchy's problem for ordinary differential systems has been, of course, the most important mathematical problem for as long as artillery has ruled over the world, as long as celestial mechanics has been the main scientific theory and success. Cauchy solved it for ordinary differential equations by a very good method of successive approximations, the so-called Cauchy-Lipschitz method; it gives the solution only locally, that is, for a finite interval of time, but at its end you apply anew the same method, and you obtain the solution for a second interval of time and then for a third and so on. Those intervals do not tend to zero because the velocity stays bounded as a consequence of the conservation of the energy; thus you obtain the solution of the problem in the large, that is, for an interval of time as large as you want. The only trouble is the huge amount of computations to be made; but we have computers now able to compute trajectories as fast as our age requires for the best and for the worst purposes—I mean for scientific satellites and for military missiles.

It has been very fortunate that our fathers had no computers for their use; thus they had to be very clever and to understand the calculus of perturbations carefully. They did so well that they discovered analytical mechanics, namely, the relations between rational mechanics, calculus of variations, and integral in variants of ordinary

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differential equations. Those beautiful and powerful theories made astronomical predictions so precise and impressive and ballistic predictions so effective and convincing that people believed mathematicians able to do anything. For instance, the famous French philosopher Auguste Comte wrote that we should succeed in solving by radicals any algebraic equation, when Niels Abel had already proved that to be impossible; and nobody worried about Henri Poincaré discovering those astonishing predictions of science to be based on divergent series, which have no meaning, except that they are asymptotic expansions.

Indeed, it became very clear that rational mechanics was the clue to all the mystery of the world when the physicists discovered the electronic structure of the atoms, each atom being a kind of solar system ruled by analytical mechanics. Very soon it became necessary to quantify that theory. Now the first quantification also used analytical mechanics; it asserted, namely, that the physical value of the fundamental integral invariant of the equations of mechanics is an integer. Thus when Rice University was founded half a century ago, the general belief was that the fundamental principles of the sciences were known, and were expressed by differential systems; the sciences and their applications—war, for instance—had been reduced to Cauchy's problem!

But quantum theory became wave mechanics, then quantum theory of fields; relativity became general relativity, then unified theory. Internal difficulties appeared in both those big theories; moreover, their coexistence became very difficult. That crisis of modern physics influences modern mathematics deeply, in particular, Cauchy's problem. From now on I mean Cauchy's problem for partial differential equations.

It had been solved a century ago by Cauchy-Kowalewski's theorem for analytic data. Half a century later J. Hadamard, influenced by H. Lebesgue's theory of functions of real variables, pointed out that Cauchy-Kowalewski's answer is not at all what the physicists ask for. The existence domain disappears when the data tend to nonanalytic functions, whereas in physics the data are precisely nonanalytic functions. Now in physics, the problem belongs to a special type: the so-called well-posed problem for hyperbolic systems. It can be called the waves problem, for its solutions have the main property of waves: they propagate with a finite velocity. It means that, for data with bounded support, the solution vanishes outside the so-called influence domain of that support; obviously that fact stays hidden as long as only analytic data are considered. More precisely, the front of the wave, that is, the boundary of the influence domain, satisfies a differential equation: the characteristic equation.

Let us state Cauchy's problem when the system reduces to one linear equation,

$$a\left(x, \frac{\partial}{\partial x}\right) u(x) = v(x),$$

where x is a point, $u(x)$ the unknown function, $v(x)$ a given function, and $a(x, \partial/\partial x)$ a differential operator of order m, that is, a polynomial in $\partial/\partial x_1, \partial/\partial x_2, \ldots,$ with coefficient functions of x; on a given hypersurface, $u(x)$ and its derivatives of order less than m have given values, called Cauchy data.

Let us write the characteristic equation of the operator $a(x, \partial/\partial x)$: denote by $g(x, \xi)$ the principal part of the polynomial $a(x, \xi)$ in ξ, that is, the sum of its highest order terms; the characteristic equation is the nonlinear, first-order equation

$$g\left(x, \frac{\partial k}{\partial x}\right) = 0,$$

which is obviously homogeneous in $\partial k/\partial x$; thus its solutions are hypersurfaces $K{:}k(x) = 0$. They are called characteristics; as I said, the front of a wave is such a characteristic.

The theory of first-order equations shows how characteristics are generated by bicharacteristic curves, solution of the ordinary differential system

$$\frac{dx_1}{\partial g(x, p)/\partial p_1} = \frac{dx_2}{\partial g/\partial p_2} = \ldots = -\frac{dp_1}{\partial g/\partial x_1} = -\frac{dp_2}{\partial g/\partial x_2} = \ldots,$$
$$g(x, p) = 0;$$

that system, which is the characteristic system of the characteristic equation $g(x, \partial k/\partial x) = 0$, is called the bicharacteristic system of the operator $a(x, \partial/\partial x)$. It is of hamiltonian type, which is the type arising in particle mechanics. It means that the bicharacteristics can be looked at as being trajectories of particles associated with waves: they are light rays when the waves are light waves.

During the years 1905–10, and also about 1920, J. Hadamard solved and studied the wave problem, that is, the linear, hyperbolic, well-posed Cauchy problem, for the second-order equation. Let us say in very modern terms what he did. He reduced the problem to its simplest case, namely, to the construction of the elementary solution, $E(x, y)$, which is the wave produced by the elementary perturbation $v(x)$ = Dirac's measure at point y; the elementary solution $E(x, y)$ is a distribution, which is a regular function in x, except on the characteristic conoid with vertex at y. Hadamard expresses $E(x, y)$ by a series, whose terms are regular functions, except the first ones, which

are distributions on that conoid. Hadamard's main guess is the first term, which gives the principal part of the singularity of the elementary solution. As Marcel Riesz pointed out, that guess introduces an invariant integral of the bicharacteristics; hence it has a mechanical meaning, namely, a conservative mass-impulse density of the particles associated with the waves.

Our age admires J. Hadamard for having associated particles with waves fifteen years before quantum wave mechanics assumed the possibility of such an association; G. Birkhoff has made that clear. Also, we admire J. Hadamard for having subconsciously used distributions ten years before S. Sobolev defined them under Hadamard's influence and twenty years before Hadamard's nephew, L. Schwartz, developed their theory brilliantly.

But by doing all that, J. Hadamard surprised his age painfully. They knew how powerfully gifted he was in number theory and analytic functions (that was why he was invited together with E. Borel to the inauguration of the Rice Institute); how, they asked, can so successful a mathematician leave pure mathematics? How can he spend so much time in solving anew a problem which had been solved by Cauchy under less restrictive assumptions—except, as a matter of fact, one: Cauchy's assumption that all the data are analytic.

We understand now very well all the importance and the difficulty of getting rid of that analytic quality of the data. But now, as we shall see, an opposite mistake is generally made: the belief that the analytic Cauchy problem and Cauchy-Kowalewski's theorem are definitely out of date.

In 1937, twenty years after Hadamard achieved his work, I. Petrowsky was able to extend it to linear and nonlinear hyperbolic systems of equations of any order. Petrowsky's result is an existence and uniqueness theorem, which was very difficult and quite mysterious, until L. Gårding recently reduced it definitely to what Hans Lewy, K. Friedrichs, and J. Schauder had reduced Hadamard's theorem about the second-order equation; namely, to the law of conservation or dissipation of energy and to very ingenious variants of that law.

That general existence and uniqueness theorem being now clear and precise, two questions occur: In the nonlinear case, where the existence theorem is only local, what can be said in the large? In the linear case, what explicit and precise information about the solutions can be obtained? Those questions respectively have the worst and the best answers. Let us begin with the worst.

The general relativity theory asserts the universe to be ruled by a differential system: Einstein's equations. A. Lichnerowicz was able to choose such coordinates that that system becomes a nonlinear, hyper-

bolic one. Thus the universe appears clearly as being a wave propagating—I should say, expanding—with the velocity of light. Hence, knowing its present state, we can compute its evolution locally, that is, for a short period of time; moreover, there is some approximate law of conservation of energy; those two facts would enable us to calculate its evolution in the large, that is, for any large period of time, if Einstein's equations were ordinary differential equations. What gives the conservation of energy is an upper bound of the integrals of some functions, when much more precise information, namely, a bound of the values of those functions, is what would make possible the solution of Einstein's system in the large. Does it mean that the behavior of the universe would become wild, still wilder, finally so wild that there would be no more any possibility for it to go on? Why not?

Something of that sort happens indeed when a regular flow becomes turbulent; such a flow also is ruled by a nonlinear differential system with conservation or dissipation of the energy; all systems of that kind, except the ordinary differential systems and some systems with few independent variables, lead to that same difficulty of solutions becoming irregular.

But the physicists apply relativity to matter whose velocity is always extremely slow compared to the velocity of light; it is under such conditions that the relativity theory is coherent, that, for instance, a given density of mass and impulse induces a unique gravity field. Under such conditions, general relativity is a correction of classical mechanics, whose differential equations are ordinary ones, having solutions in the large; hence, under those conditions, the calculus of perturbations should solve the relativistic problem in the large.

Einstein's equations, however formally beautiful they may be, have no properties, no use, no physical meaning, until we consider them as being a second approximation, the first one being an ordinary differential system.

Consider a much simpler nonlinear system; the Navier-Stokes equations which rule viscid flow. They lead to the difficulty stated above, and now there is no escape. Why should not the solution of Navier-Stokes equations become irregular, let us say turbulent?

For two-dimensional flows there is no turbulence; the proof was recently achieved by Ladyzenskaja. But our space is three-dimensional, and turbulent flows can be observed everywhere. As a matter of fact, it is possible and even easy to show the existence in the large of a regular or turbulent solution of Cauchy's problem for Navier-Stokes equations. But, if that solution is turbulent, then its uniqueness is doubtful. What can be the physical meaning of such a solution—turbulent, undetermined, hence unstable? Moreover, Cauchy's prob-

lem is no more a natural one for hydrodynamics. How could you experimentally give an arbitrary velocity at initial time to a fluid, as you give to a pebble, a particle, a missile? Should we look for a statistical approach to hydrodynamics? Its success in particle mechanics is due to an integral invariant, which gives the definition of a probability in the phase space. There is nothing similar in hydrodynamics, and no statistical approach has been satisfactory. Then should we look for a special type of solutions of Navier-Stokes equations, for instance, the almost periodic type?

Let us sum up those hesitations. Either the study of turbulent solutions of quasi-linear systems with conservation or dissipation of energy is a fruitful problem, but certainly a difficult one requiring original methods, or the turbulence is a mystery deeper than the nonlinear Cauchy problem in the large; perhaps, even, it is deeper than the theory of nonlinear differential equations, and we have to abandon last century's belief that such equations can express all the laws of macroscopic physics.

Science will not stop in front of too general problems and too hopeless difficulties. It happened two centuries ago, when d'Alembert calculated the force which a two-dimensional, steady flow exercises on an obstacle and obtained a force orthogonal to the general direction of the flow. Trivial experiments show that force to be not orthogonal but parallel to the flow; at that time, no other cases had been observed. That paradox stopped theoretical fluid mechanics for a century; it was thought to be wrong. Then physicists discovered how the wake of the obstacle gives rise to a force parallel to the flow, how for obstacles called fine profiles the wake disappears, the flow is potential, and d'Alembert's result holds. Then technicians used those fine profiles and d'Alembert's computations for wings, which carry aircraft without slowing it down—at least in first approximation—and also for turbines and ventilators—you now see everywhere flows satisfying d'Alembert's paradox. When you look at a bird, then, what nobody could guess a century ago strikes you now; birds know and use perfectly well d'Alembert's paradox. A flow satisfying that paradox is very regular, quite simple, and an extremely special solution of equations of hydrodynamics; the study of that kind of solution constitutes an elementary, nice, and useful theory.

Such an example shows how it is fruitful to obtain very explicit results about problems as simple as possible, still more fruitful when computers are available. Well, consider the linear, well-posed Cauchy problem for a hyperbolic operator $a(x, \partial/\partial x)$: it reduces to the construction of the elementary solution $E(x, y)$ of $a(x, \partial/\partial x)$. Do not assume $a(x, \partial/\partial x)$ to be of second order, as J. Hadamard did. But, at

first assume its coefficients constant: $a = a(\partial/\partial x)$; then obviously, $E(x, y) = E(x - y)$ is the Fourier transform, or more conveniently, the inverse Laplace transform of $1/a(\xi)$. But that very simple expression does not give very explicit results; it does not show even the analyticity of $E(x - y)$ for x outside the characteristic cone with vertex at y. That is the reason why G. Herglotz and I. Petrowsky, assuming $a(\xi)$ homogeneous, transformed that first expression of E. They suppressed the exponential contained in the Laplace transform and expressed E by periods of abelian integrals on the projective complex variety $a(\xi) = 0$. Their expression of E is very explicit and handy; for instance, Herglotz applied it to the propagation of light in crystals, that is, to a fourth-order equation. However, their work has been difficult; it was partially done by Herglotz about 1925, but it was achieved by Petrowsky not sooner than 1945. Petrowsky introduced the topology of algebraic varieties for studying the support of E; he used deep topological results, discovered by S. Lefschetz about 1920 in this country, where mathematics already had a dozen apostles, three of which I have to quote today: G. Birkhoff, S. Lefschetz, and M. Morse.

Herglotz-Petrowsky's assumption, that the coefficients are constant, is too special. For instance, the study of transsonic flows uses linear equations with variable coefficients. The simplest one is the well-known Tricomi equation. Let us consider a more general type and call Tricomi's general operator any operator $a(x, \partial/\partial x)$, whose highest-order derivatives have linear coefficients, the next highest order derivatives have constant coefficients, and all the others have null coefficients.

Well, the elementary solution $E(x, y)$ of an analytic hyperbolic operator $a(x, \partial/\partial x)$ is analytic for x outside the conoid with vertex at y; there is an explicit expression for the principal part of its singularity; as for second-order equations, that expression has a mechanical interpretation in terms of trajectories and conservative mass-impulse density of particles. Moreover, that expression is the elementary solution itself, when $a(x, \partial/\partial x)$ is Tricomi's general operator; then it is a special function of several variables, which would deserve some more investigations.

The proof of those very explicit informations about Cauchy's problem relies at first on a new functional transformation having some of the properties of a Laplace transform but some very convenient others. It is defined by an integral connected with Herglotz-Petrowsky's expression of Laplace transforms of rational homogeneous functions and also with residue theory in several complex variables.

The elementary solution is the transform of the solution $U(\xi, x)$ of the simplest Cauchy problem,

$$a\left(x, \frac{\partial}{\partial x}\right) U(\xi, x) = 1,$$

Cauchy's data null on a hyperplane ξ. F. John has been the first to use $U(\xi, x)$, which is now called "unitary solution of a."

The above-mentioned properties of the elementary solution result from the properties of the unitary solution, which has to be studied for complex ξ; the old Cauchy-Kowalewski theorem has to be applied and, moreover, to be completed there, where the hyperplane ξ is characteristic. Namely, U is not single-valued; but a holomorph mapping can be explicitly given such that its composition with U is holomorph; the functional determinant of that mapping vanishes on the characteristic tangent to ξ; there U ramifies and its principal part is given by a quadrature; the bicharacteristics generating that characteristic and that quadrature have the usual mechanical meaning: trajectories and mass-impulse density of the particle associated with $a(x, \partial/\partial x)$; moreover, U itself is explicitly known for Tricomi's general operator.

There is now an elementary proof of those properties of the unitary solution U, simply by a change of variables and by successive approximations. It should have been given a century ago. But for half a century, Hadamard's warning that there are also nonanalytic Cauchy's problems has been understood as a warning against the analytic Cauchy problem. The study of its singularities has been neglected, whereas it is the clue to the relations between waves and particles, the clue to the singularities of Cauchy's problems with no regular data—the study of the elementary solution being merely the simplest of those problems.

Instead of speaking about hyperbolic equations, I could have spoken about elliptic equations, the calculus of variations, and the impressive progress of its direct methods; then I would have called upon our intuition of equilibrium instead of wave propagation; I would have quoted Marston Morse, Schauder, J. Nash, de Giorgi, Ladyzenskaja, Oleinik, J. Moser. . . .

I could have also spoken about very general types of equations, about highly undetermined problems without boundary conditions, about existence and nonexistence theorems, about the propagation of singularities and about the general system with constant coefficients; then I would have traced the origin of the problems and of their solutions to the elliptic and to the hyperbolic cases, I would have quoted

Banach, Hans Lewy, Hörmander, Ehrenpreis, and Malgrange and his use of very recent algebraic theories.

I could have spoken about topology, used our intuition of geometry, and said how differential geometry influences topology, which influences algebra deeply.

There are so many other vital branches in mathematics! And also this new language that their use requires plays a crucial role. In any case, what has to be pointed out is the importance of the connections between the different parts of the sciences. The richness of their discoveries, the power of their methods have to be largely dominated and managed by scientists.

Once, when I was rather young, Henri Lebesgue attacked our generation: all of us were specialists, no one deserving to be called a mathematician. Well, let us hope that presently young people will have such strength and receive such help that later on they will deserve that title of mathematician, or even the title of scientist, by their mutual understanding and their refusal to confine themselves within a specialty. If so, then the future will be what it shall be: not trivial but unforeseen.

MARGARET MEAD

Human Capacities

It would be an interesting exercise to choose a topic for today's lecture which would be appropriate to such a distinguished and varied galaxy of speakers. So far I do not regret the topic I have chosen; it seems to fit in well with many of the predictions made and much of the optimism expressed in the last three days.

Every time men are confronted with tremendous change in their own society, every time they have the experience in an important situation, of meeting other men who are different from themselves, this precipitates a crisis which leads them to wonder about human capacities. A crisis of this kind takes many different forms, but the wondering almost always has to do with the capacities of other people—some other group does not have the capacity to deal with the state things are in, whatever that state may be. Or does it?

This process has been going on for a very long time, possibly more than a million years. As far back as we can go, we can imagine small wandering groups of "human" creatures going their own way, each group convinced at least of their own "humanity" (1). So far as we know, no group has ever doubted its own humanity, but many groups have defined themselves as *the* human beings and have given various other names to other peoples. If another group appeared to be inferior, they treated them in one way. But if the other group seemed exceedingly superior, they explained the superiority not by denigrating themselves but by putting the others in the position of gods. They themselves were still the only human beings. This kind of thing has happened fairly frequently. Sometimes when the first Europeans landed on a South Sea island, sailing in on a ship that was larger than anything the islanders had ever seen and magnificently equipped, they

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were taken for gods—an impression that vanished quite rapidly on closer contact.

And we can imagine such a group of very early human beings, wandering around, looking over to another hill and seeing some other creatures, and not being sure whether they were humans or animals or creatures that could be turned into prey—wondering whether they were creatures to be fled from or appeased or merely avoided or whether they could be treated as people like themselves. This has been going on right through human history, this worrying as to whether some other people, who look like human beings, really are human beings. Each time new groups of people have been discovered, it has precipitated a crisis. In the period of the great European explorations, when Africa and the New World and the South Seas were opening up, Europeans raised the question as to whether the newly discovered peoples had souls and were to be included in the Divine Atonement. After a great deal of discussion, the Roman Catholic church decided that they were human beings who could become Christians, too, and who, once they were baptized, could not be enslaved. Some Protestant denominations were slower in working out this position. Even today there are denominations which have not quite coped with the theological implications.

Today we are faced by another of these crises, one which has been brought about by two concurrent, related sets of events.

Now, for the first time, we are having to share political action with peoples of exceedingly varied levels of civilization, whose historic past differs one from another and from our own. We have to include in one forum, one world forum, many peoples who, a generation ago, had cultures without a written language and without any knowledge of the wider world; we have also to include other peoples whose ancient civilizations we have thought to be effete or decadent or mystical, but who are coming into the modern world with quite alarming speed and efficiency. All of us, especially those of us who are very conscious of what is happening in the world, are faced with the problem of re-evaluating our judgments about these other peoples—not necessarily in genetic terms, but in terms of their experience. As always, we worry. But this time many of our worries are phrased in questions about time: Will the peoples of the new countries—the new countries of Africa, the new countries of southeast Asia—learn the kinds of technology and the kinds of political behavior we think desirable quickly enough? Given their historic past, so different from our own, can they take hold of the modern world quickly enough?

At the same time, in our own society, we are facing a related crisis which has been precipitated by rapid and revolutionary technological

change. One of our speakers in the last three days said that man has made more progress in the past fifty years than was made in the whole previous history of the human race. But of course one's interpretation depends on just what one means by "more." I am not at all certain that it is as difficult for us to move from one generation of computers to another as it was for man to take the steps involved in picking up a stone and using it as a tool and then getting the idea of making a tool and then getting the idea of a toolmaking object: inventing a tool to make a tool. We have no way of measuring the difficulty of steps of this kind. Conceivably we might regard the change involved in moving from an earlier stage to the stage in which human beings had an organized language and an organized set of tools and an organized set of relationships—so that children born into that society were in the fullest sense human beings—as equal to or greater than the change we have lived through in the last fifty years.

But there can be no doubt that the change we are experiencing is the most staggeringly rapid in man's history: that no other generation in human history has had to live through, absorb, and deal with greater change within a single lifetime. And, of course, those who have had to make the greatest adaptation are the old people, the oldest generation now living. There is a belief that only the young can cope with all these modern developments; in fact, it is the old who have had to cope with the largest number of them. The very young were born into a changed world, but older people have had to learn, step by step, everything that is new, have had to absorb it and accept it. This has been pretty trying. But at the same time, the very primitive peoples who have had an opportunity to come into this modern world have been asked to skip a thousand years, even two thousand years, in a decade; in some cases they have been able to do so. Nothing like this has ever happened before in human history. It may never happen again. We do not know.

Faced by the problem of this rapid change, we also ask: What are the potentialities of the human mind? Is the mind good enough to cope with this tremendous advance in knowledge? Or has civilization outstripped the ability of its inventors to use it? Phrased in this way, the question may perhaps represent an overvaluation of the state of knowledge in relation to the ability of human beings to use that knowledge.

In the recent past the same question has been phrased in various other ways—often in terms of race. In the nineteenth century and the early twentieth century we had an outburst of beliefs about the innate superiority of the "Nordic" peoples, who were believed by many to be responsible for almost every wonderful accomplishment on earth.

Some people phrased their questions in terms of the potentialities of uneducated working-class groups; for a long time, for example, there was a great deal of worry for fear that all the less intelligent stock had sunk to the bottom of society. But this has never been confirmed by any careful research. In our own society a great many similar questions were raised about subordinated groups: ethnic groups who had been kept in socially inferior positions and who then showed less ambition than did other Americans who were certain that any one of them could be President. The changing ethnic composition of the United States worried us, and we passed immigration laws that favored only a small proportion of the peoples of the world—some of the blond peoples (or peoples we thought of as blond)—over all others. The general theory was that this would improve our originality; so far, it has not.

As recently as 1933, in the midst of the great depression, an article appeared with the title, "Are All Men Human?"—an extreme phrasing of the question we have been asking (2). Taking off from other published work, the author asked, half satirically, whether the difference between the most superior and the most inferior human being was not greater than the difference between the most inferior human being and an animal, and proposed the conveniences of an affirmative answer. When I read the article, I was on the Sepik River in New Guinea (where reports about the closing of the banks in the United States had just reached us); the primitive people with whom I was working, the Tchambuli, showed no difficulty in grasping very rapidly a large number of things they had never heard about before.

But essentially questions of this kind are not new. In some form, such questions have been asked by every group in human history. What changes is the form the question takes and the object of scrutiny. Sometimes the questions have to do with women: Do women have a soul? Do women have brains? Sometimes (when constancy is in vogue) they are regarded as too variable; at other times (when variability is good), they are charged with being less capable of change than men. Whatever quality is currently under discussion, the question is raised: Do women have it or not? (Can women acquire scientific objectivity? Can women be great artists?) This is a kind of inquiry which may be expected to recur periodically. I see no reason to believe that the matter will be settled quickly.

What we have to expect is that the basic question will only change its form. With more scientific knowledge, some of the old forms will disappear, but new forms will then emerge. Confronted by some new situation, men will still ask: Are human capacities up to it? Are the human capacities of present-day groups adequate? If they are, will

they remain so? Or will they deteriorate, as Muller is convinced they will? And if human capacities do deteriorate in the future, as he believes they will, will men have to depend on new mutations to match the new machines (3)?

Mutation is a familiar science-fiction solution to the problem. As we are, science-fiction writers imply, we can't do much with things—but we can be changed. In one version, *Talents, Inc.*, by Murray Leinster, a set of people with talents that are, by and large, disregarded in the present-day world (a water-dowser, a finder of lost objects, a lightning mental-arithmetic calculator, etc.) have been built up into a team; working together, the members of Talents, Inc., are able to solve the problems of a galactic world (4). A great many other people, phrasing the issue in a less fantastic and spectacular way, nevertheless share the belief that we must somehow have many more of certain kinds of human beings, of whom we do not now have enough, in order to tackle the complicated problems before us.

The belief that available intelligence is inadequate in amount or kind to meet our coming needs has been intensified by the present state of the physical sciences. Increasingly, during the last fifty years, physical scientists have become isolated from the community at large, particularly at the top levels of these sciences. Fifty years ago, almost everyone who went to college studied physics, and teachers of physics had to instruct a great many nonphysicists. In fact, they had to teach a great variety of students—students who cared about poetry, students who cared chiefly about living things, students with very concrete minds, students who were primarily sensorially related to the outer world—all kinds of strange people whom no physicist would want in his laboratory. Even girls. (I am, of course, taking physics only as one example, but it is perhaps the best example of what has happened.) Then, with the development of the elective system of studies, teachers of physics and higher mathematics, and so on, were able to scare off anyone who did not have the kind of mind they themselves wished they had (I think this is a fair definition), the kind of mind they found most congenial to their way of teaching. One result of this has been that natural scientists have spent more and more time talking to one another and have become less and less good at talking with other people; and, in turn, other people have become much less able to listen to (talk with) natural scientists. It is as if, brick by brick, a wall of noncommunication has been built up, and now those who are inside feel uncomfortable when they take a walk outside. In *Science and the Common Understanding*, Robert Oppenheimer described the "vast house" of science as an "open house, open to all comers," but immediately afterwards he pointed out that a man "is

lucky if he has a bit of familiarity outside the room in which he works" (5). In *The Open Mind* he wrote poignantly of the loneliness of the scientist and the artist in the modern world, especially the scientist who, in working at the frontier of a science, finds himself "a very long way from home" (6). He stressed teaching as the means of keeping communication open. But elsewhere, shifting his stance somewhat, he has spoken of the necessity, the regrettable necessity, of popularization. Up to the present, the general response has not been to attempt to open new doors of communication; instead, we have been putting our main effort into producing more natural scientists (7).

As far as we know, such breaks in communication are not necessary. It is probably possible to teach the public enough about the new ideas in the physical sciences so that people can live in terms of them and use them quite comfortably. Throughout the ages, it has been possible to teach people who grew up in one kind of world how to live in a different kind of world, to induct into higher learning whole sectors of a population who came from homes without the slightest grasp of what higher learning was about. The contemporary world is not unique in having a great mass of people who are unfamiliar with new knowledge.

The anxiety about the present state of the world is sometimes expressed in arguments as to whether, eventually, the "computers" are going to take over. This is, of course, one way of arguing about whether the natural scientists are going to take over. Arguments about computers reflect a tremendous fear that somehow science will dehumanize people—turn them into exploited creatures called "human components" and generally degrade the human position of human beings. Feeding into this there is the perfectly genuine fear that, under present conditions, science may destroy the entire world it was designed to protect and advance. I shall come back to this.

But first, it is important to recognize that in considering the whole question of human capacities there is one new element. In the past the question of who was and who was not human was decided by ecclesiastical fiat, by a prophet's vision, or by a conqueror who could impose his views. Even now, as the newly released colonial peoples are redefining their position in the world, we are seeing the phenomenon of whole peoples rewriting the history of their past. By and large, up to the present, political and ideological activities have been supported—or opposed—by political and ideological concepts. Now, for the first time, we have a great deal of scientific knowledge to bring to bear on the same problems.

Today we know who the peoples of the world are. This information is recent. Up to, even during, the Second World War, fantastic esti-

mates were made of "lost tribes" living somewhere in the center of New Guinea; these estimates were, of course, built up from explorers' accounts of peoples they had glimpsed but never really seen. But today even this stronghold of mysterious peoples has been breached. And we can say with some assurance that all the peoples on this earth belong to one species, as a species is at present defined. We have little hope of finding anywhere on earth a people who belong to a different species, however much such a discovery would cheer up various groups among us.

And we know enough about the ways in which ideas have diffused in the past and about the ways in which children learn in the present to make a good many responsible propositions about human behavior. We know, for example, that the differences between what an Arapesh native of New Guinea and a Rice undergraduate can learn do not result from differences between their brains. The brightest Arapesh is probably as bright as the brightest Rice undergraduate, and since in Arapesh society no very severely defective individual can survive, as he can in our society, the intelligence average in Arapesh may be a little higher than our own. Nevertheless, even a very brilliant Arapesh—a man who was capable of high-level thinking—got a headache whenever he tried to think for five minutes. When I put questions to the Arapesh that no one had asked them before, when they were made to think about linguistic form or any one of a whole series of things that were inexplicitly and inarticulately present in their badly organized, thin, very thin, poor culture, in which no one counts beyond 24, their heads ached. Yet we have no reason for thinking that they were not born with the same kind of brains that we have. They were unable to think because they lacked the equipment for thinking—the cultural equipment.

If we consider the very simplest people we know anything about: a people who can count only to 2 or 3, who have no calendar and no sense of the past, whose version of their human lineage includes three generations of people and then a cockatoo; and then if we consider what can be done in any laboratory on this campus or the complexity of the ideas that can be discussed in its classrooms, we have some notion of how far contemporary men have come. The difference between ourselves and any very simple people is the result of culture: the long accumulation of new methods and new knowledge and the development, over a very long time, of ways of transmitting that knowledge to new generations and to members of other cultures, laterally.

Using this scientifically based information, we can take another look at human capacities before we try to answer the questions we

have been asking: Has the human race, in all its divisions, the capacities to deal with today's events? Are the calculations we need to make in order to move into the future—the calculations necessary for computer programing or for sending out space ships—too complicated for our present brains? Would we do better to concentrate on a research design for the future which would make it possible for men to preserve the genes of a very few highly gifted people, so they could be replicated and multiplied for future use (8)? Or are there already present, in the full range of living human beings, the capacities which will be needed in an even more complex world?

On the question of the actual use of the brain, it has been estimated by Lorente de Nó that man is at best using his brain at about a tenth of its full capacity. If this is indeed the case, then we have, even now, only begun to tap the human ability to learn whatever human beings can invent, institutionalize, develop, and transmit to other human beings. And as we develop, each new development opens new possibilities, that is, in effect, makes us brighter.

There are, of course, people who think that each new development, in effect, makes us stupider—that each new and more difficult stage of knowledge is potentially available to a smaller number of people who alone are capable of dealing with a higher stage of complexity. The present lamentable state of our schooling leads to results that lend themselves to this interpretation. Measured by school standards, a large proportion of the population is condemned to be "stupid" or "defective"; but the proportion of those in the general population who are "defective" is much smaller. The fact is that when the pupils on whom this judgment has been passed leave school and face the real situations of the real world (for which there is no simulation in the school situation), many of them do quite well. As we concentrate on our narrow school standards, we continue to find more students who seem to be unable to deal with the difficulties, and we continue to apply to the world at large the judgments made within the school situation.

Yet the level of the American I.Q. has been rising. We do not attribute this rise to a change in the population balance brought about by our immigration laws; instead, we relate it to the fact that contemporary children are exposed to a more complicated world and begin to learn at age five what an earlier generation learned at ten or twenty, or perhaps did not learn at all. Observation of a tribal group in the process of moving into the modern world (in, perhaps, one of the new African states) can help us to understand better what is involved. It is much more difficult, initially, to grasp geometrical thinking for a child who lives in a circular hut that is not very

circular, with a conical roof that is not very conical and that tips slightly to accommodate the branch of an overhanging tree, than it is for a child who lives in a modern setting. The fact is, we build our increasingly scientific knowledge into our culture at every turn and at every point, and simply by living within the culture people absorb it and find it easier to master. So one must take into account, in every culture, not only explicit efforts to teach but also the inexplicit and inarticulate learning that goes into enculturation. A better understanding of this total process is one contribution that the sciences of anthropology and comparative psychology can make to our estimates of human capacities.

There is, however, another set of problems which may be more immediately germane to the survival of mankind. These problems are concerned with emotional aspects of human life, aspects which are the special province of psychoanalysis. Especially relevant is the question of the extent to which human emotional reactions may be regarded as innate and shared with other living creatures and the extent to which they are survivals from pre–*Homo sapiens* stages of human development. Psychoanalysis deals with the residues in adult behavior of impulses and emotions that have been imperfectly civilized in the process of reaching adulthood. Every functioning human culture has found ways of channeling the biologically given in human beings so that those born into a specific culture are able to learn and mature and become members of their culture. But no culture has ever done this perfectly. In every culture there are lacunae; in a changing culture these may be considerable, and the number of people for whom the organizing procedures have somehow failed may be relatively large. Particularly relevant here is the mode of thought for which Freudians use the term "primary process," which some people call "artistic thinking," and which some people describe as "irrational"—the kind of thinking that is characteristic of dreams, in which associations are based on emotion and on types of analogy that are not subject to digital thinking. As yet, we do not know how intractable these things are. We do not know to what extent the humanity of human beings is dependent on the cultural restructuring of impulse structures that were appropriate to "man" at a precultural stage, when his characteristic modes of behavior were closer to animal behavior than to human behavior, as we now define it.

These are problems on which we shall have to work. Part of our difficulty in working out more appropriate forms of political behavior lies in our lack of knowledge about this aspect of human capacities. For political behavior is very firmly grounded in types of behavior which are basically emotional, not rational.

Dr. Shannon ended his lecture with the hope that if computers become more intelligent than man, we shall also find ways of making them wiser. At present the very speed of change has made it all but impossible for us to make use of the accumulated wisdom of individuals. In other more slowly changing societies, individuals have acquired wisdom by living long enough and absorbing enough of their culture so that they have attained a certain objectivity and an ability to sort out alternatives. In our own society we may be able to give computers wisdom, in this sense, by a very rapid build-up of experience. In addition, we may be able to build into computers another ability of which we are in great need—the ability to think freshly. Human beings cannot, of course, strip themselves of old solutions in order to find new ones; they have to find ways of building on the past. Nor are we certain, as yet, that it is possible to build an unprejudiced computer. Computers are, after all, built and programed by men, some of whom have a feeling at least some of the time that their creations are alive and should not be too different from themselves. So one must assume that contemporary conceptions are being built into computers and into programing. But possibly we can build into computers the ability to sort out alternatives and to tackle problems freshly, free of presuppositions, earlier hypotheses, and older ideas about how things should be done, so as to arrive rapidly at better solutions.

In *The Voice of the Dolphins*, Leo Szilard—who at the time took a very dim view of human capacities for thought—constructed a research institute in which Soviet and American scientists learned to communicate with dolphins, who told them how to behave sensibly. But, as you will remember, the institute eventually broke down, and people began to say that there had been no dolphins. But in the last sentence Szilard commented that "it is difficult to see . . . how the Vienna Institute could have accomplished as much as it did if it hadn't been able to draw on considerably more than the knowledge and wisdom of the Russian and American scientists who composed its staff" (9). This fantasy, conceived of by a scientist, expresses very well the kind of despair, the lack of faith and trust in human potentialities that is bred by our present situation. For we are very far from knowing the solutions. In particular, we are very far from knowing the extent to which human beings can be re-educated emotionally.

We do know that extraordinary transformations can take place at the cognitive level. I myself observed one such transformation among the Manus of the Admiralty Islands (10). In 1928 the Manus were a Stone Age people who had no knowledge of geography or history,

whose political organization could hold together a group of no more than about two hundred people, who had no script, and whose mnemonic devices consisted of such things as sticking small twigs into a larger twig in order, for example, to add up the number of pigs killed for a ceremony. But only twenty-five years later, in 1953, when I returned to the Admiralties to make a restudy of the Manus, I could say to a man who had been a little houseboy during my earlier stay, "Start the generator and take this informant out and make a bilingual tape on the Magnicorder." In 1953 the Manus were a little critical of our electronic devices because, unlike the earlier machinery which they had seen, the new machinery was inclosed in boxes, and only the start and stop buttons were visible. So it was more difficult to understand. But if we would only let them see the channel charts, they said, they could understand how the machines worked without too much difficulty. And in the same twenty-five years in which they had developed this high degree of sophistication about machines, they had moved from a kind of thinking in which they were unable to conceptualize the world beyond their own island to a kind of thinking in which they could understand their place in a trusteeship under the United Nations and their relationship to Australia, to London, and to the entire world.

In these twenty-five years the Manus had experienced a cognitive transformation. Not very many peoples have, but we know that cognitive transformations are possible, because they have taken place. Unfortunately, we know much less about the transformation of men's loyalties from smaller to larger groups, the transformation of their expectations about life—their goals—and of the sacrifices they are willing to make in realizing these expectations. We know much less about the new forms that must be invented, without delay, if we are to get the kind of control of our scientifically based types of warfare that will protect us from catastrophic destruction.

This celebration is an occasion for optimism, and speakers have expressed their optimism in various ways. Dr. Glennan expressed the belief that man's very selfishness, tempered by wisdom, will lead him to choose understanding, co-operation, and human and material advancement over disunity, suspicion, hatred, and ultimate destruction. Other speakers have expressed their belief in man's rationality, in his capacity for disinterested behavior, and in his goodness. Only by implication have we been reminded of the darker side of the picture—our fears about man's irrationality, our doubts about man's goodness, our pessimistic assessments of man's capacity for destruction.

But we have still not fully confronted our uncertainty about the basic relationship of aggression and warfare. Much of our present

research leads to the general conclusion that the greatest danger of war comes not from those of man's instincts which we have defined as "bad," but instead from those we have defined as "good"—from the willingness of men to fight and die for the things they value. Throughout history, forces by which men have been passionately moved, which place an urgent and almost irresistible claim on their lives, have been summated in this willingness to defend women and children, to defend land, to defend the name of a country or a religion or a set of ideals—ideals in the widest possible sense, as they are subsumed under words like "freedom" and "progress." What we have to worry about is not aggression as it is expressed in the will to power, destructiveness, and violence. Rather, what we have to worry about is men's agelong willingness to die for the things they value beyond their own lives.

Unquestionably, this willingness to fight and sacrifice one's life goes back a very long way—far beyond the life of our present species. During recent field work in Southern Rhodesia and Kenya, Sherwood Washburn made extraordinary motion pictures of troops of baboons. In one sequence we see a troop which has been disturbed in its feeding by the approach of some predator. Sensing its danger, the troop begins to move, the females and infants running ahead and the mature males drifting toward the rear periphery. As the carnivore approaches, the males turn, open their mouths, and bare their teeth in a gesture of bravery fantastic to watch (11).

Throughout the history of our own species, men have developed more and more effective tools, weapons, and battlements for the protection of larger and larger groups of people against other men. Today, we have reached a stage where almost the whole human race can become involved simultaneously in demands for self-sacrifice, on the one hand, and in the mortal dangers which may ensue, on the other. What we must hope for now is a rapid transformation, through which living human beings, everywhere in the world, will learn that this willingness to defend, as it is expressed in a willingness to die, has ceased to be meaningful. When men fought and died for what they valued, they did so in order that other living human beings—parents, children and grandchildren, brothers and sisters, allies—would continue in possession of what was valued. But today all these others too would die; the values through which men live are no longer served by dying for them.

In 1959, at a rather similar symposium at Brown University which brought together a distinguished group of speakers, Isidor Rabi said that he was not worried: he trusted man's instinct for self-preservation (12). Actually, the belief that human beings who live in a

culture, who have learned to care for their children and grandchildren, their relatives and friends, and who have fidelity to the past and hope for the future are motivated by an uncomplicated "instinct for self-preservation" is not borne out in history. Man's instinct for self-preservation has always been capable of transmutation into suicidal self-sacrifice. Acting in terms of this instinct, a man will try to swim if he is thrown into the water; he will try to break out of a burning house—providing his child is not in the next room; he will try to walk across a desert when he is lost and all alone. But in our present situation we cannot trust to this instinct to save us, because it also becomes embodied in overriding kinds of learned behavior that may be expressed in a willingness to die in order to protect the well-being of others. Indeed, we have no reason to believe that human *soceties* have any built-in capacity to save themselves. On the contrary, over and over again, societies have pursued a suicidal course in the pursuit of aims they have valued above the measures necessary for survival.

The central problem with which we are faced today is that of devising new political institutions which are founded on man's emotional capacities for loyalty and which will enable us to transmute once more our biologically given capacities for self-sacrifice so that, instead of dying, we will be willing to live and work for what we most highly value. As far as man's capacities are concerned, his capacities to learn and learn enormously, the only question is that of time. Can we learn fast enough?

We know the kind of learning situations through which groups of Stone Age men have moved into the modern world within one generation. If we believe the task itself is possible, we can set up the necessary learning situations. But we must also recognize that the transmutation of age-old loyalties is a formidable task. If we succeed, then the journey ahead of man will be even more magnificent than the journey by which the human race came from the Stone Age into the present.

References

1. Although it is now well known that species antecedent to *Homo sapiens* (not necessarily in the direct line of ascent) were culture bearers, we have not as yet devised a satisfactory inclusive term by which to refer to *all* those of whom this capacity has been characteristic—*Homo sapiens* and various predecessors.
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6. J. Robert Oppenheimer, *The Open Mind* (New York: Simon and Schuster, 1955), p. 138.
7. A further suggestion has been made that another source of difficulty in the communication between natural scientists and others is to be found in the prominent position of Continental European scientists today in the natural sciences; in this matter, there has been a considerable difference in the tradition of participation in learning on the Continent, on the one hand, and in England and the United States, on the other, and today, with Continental natural science in the ascendancy, the European sense of the scientist as a man apart feeds into our current views of the scientist as a man isolated by his special knowledge. (Rhoda Métraux, personal communication.)
8. Muller, *op. cit.*
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12. Brown University Convocation: "Man's Contracting World in an Expanding Universe," October, 1959, Providence, Rhode Island. Professor Rabi was a discussant in the symposium "The Physical Universe."

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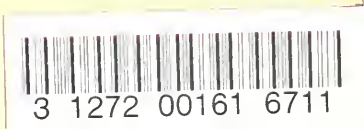
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